Walter W. Bradley.

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING SAN FRANCISCO
OLAF P. JENKINS, Chief

Vol. 43 JANUARY, 1947 No. 1

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

printed in CALIFORNIA STATE PRINTING OFFICE
70558

STATE OF CALIFORNIA

Earl Warren, Governor

DEPARTMENT OF NATURAL RESOURCES

Warren T. Hannum, Director

DIVISION OF MINES

Olaf P. Jenkins, Chief

Headquarters
Third Floor, Ferry Building, San Francisco 11

District Offices

State Building, 217 West First Street, Los Angeles 12
631 J Street, Sacramento 14
Box 445, Redding

The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the State; exhibits of minerals, rocks, mine models, etc., a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles and Sacramento district offices.

The principal publications of the Division of Mines consist of the quarterly periodical *California Journal of Mines and Geology*, issued in January, April, July, and October of each year, and a series of *Bulletins*. Mimeographed *Information Circulars* and *Announcements of New Publications* are also released periodically. A list of publications will be sent free upon request.

ORGANIZATION AND PERSONNEL

(Effective July 1, 1947—99th Fiscal Year)

GEOLOGIC BRANCH: Parker D. Trask, Supervising Geologist; Lauren T. Wright, Associate Geologist; Charles W. Chesterman, Assistant Geologist; George L. Gary, Mineral Technologist; Richard A. Crippen, Jr., Supervising Geological Draftsman; Edward J. Rhodes, Geological Draftsman.

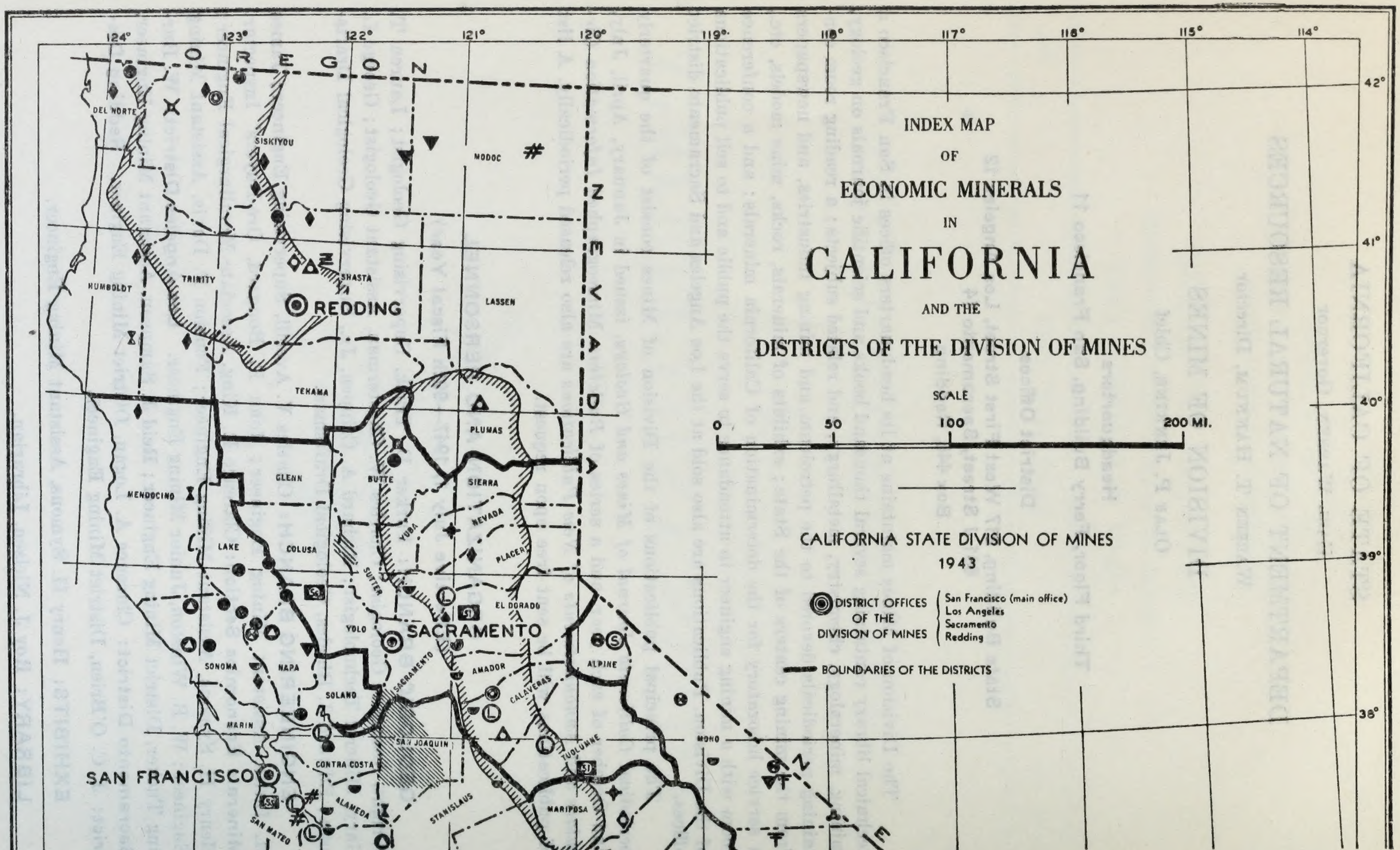
ENGINEERING BRANCH: Charles V. Averill, Supervising Engineer; James M. Little, Assistant Mining Engineer; John F. Bongard, Ore-Buyers' Inspector. **Minerals Economics Section:** Clarence R. King, Associate Metallurgical Engineer; Henry H. Symons, Assistant Mining Engineer; Fenelon F. Davis, Assistant Mining Engineer; W. B. Winston, Junior Mining Engineer. **Los Angeles District:** W. Burling Tucker, District Mining Engineer; Reid J. Sampson, Assistant Mining Engineer. **Sacramento District:** Clarence A. Logan, District Mining Enginer. **Redding District:** J. C. O'Brien, District Mining Engineer.

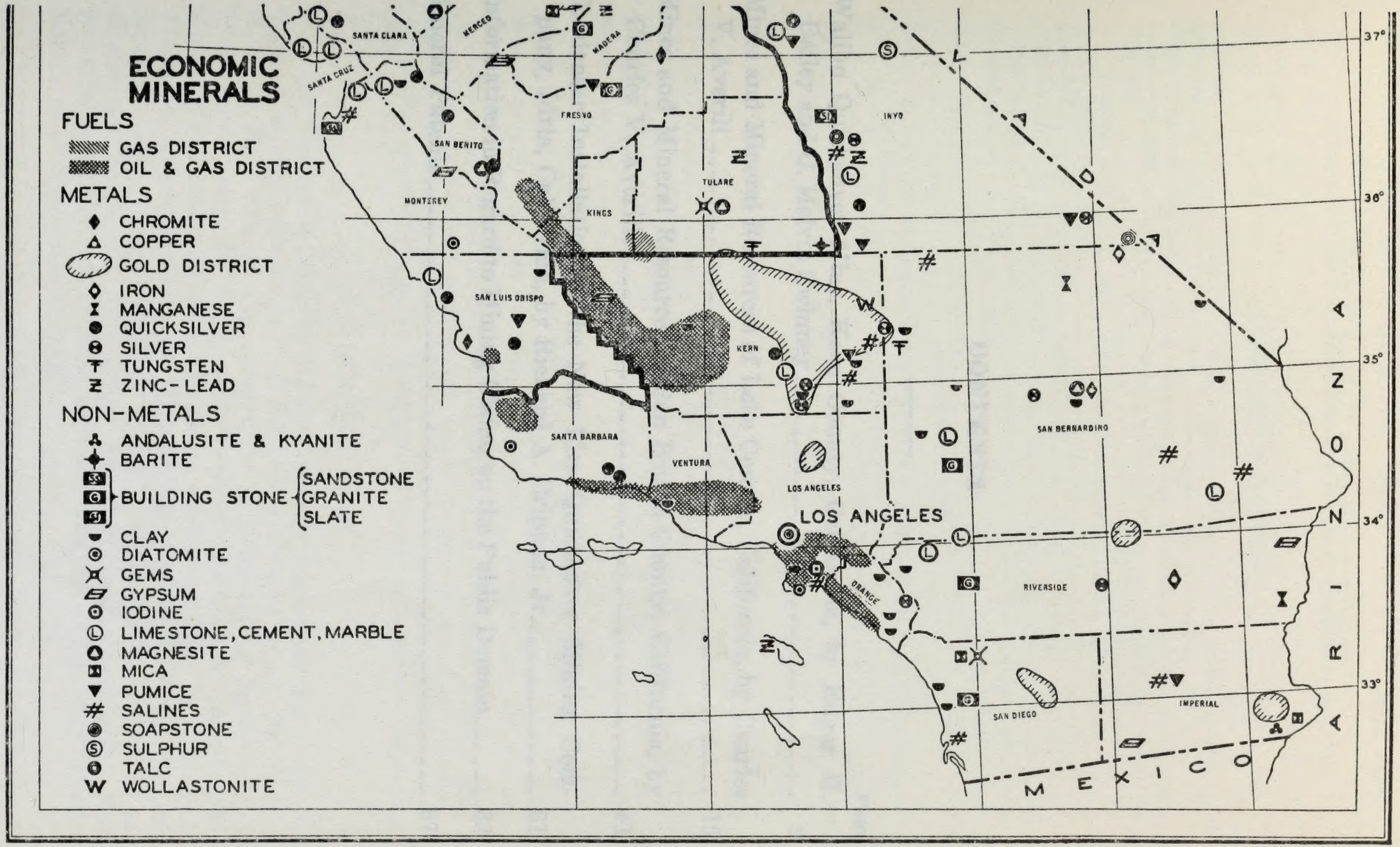
EXHIBITS: Henry H. Symons, Assistant Mining Engineer.

LIBRARY: Roy J. Nielsen, Librarian.

EDITORIAL SECTION: Elisabeth L. Egenhoff, Editorial Assistant.

2—70558


INDEX MAP
OF
ECONOMIC MINERALS
IN
CALIFORNIA
AND THE
DISTRICTS OF THE DIVISION OF MINES
SCALE
0
50
100
200 MI.
CALIFORNIA STATE DIVISION OF MINES
1943
DISTRICT OFFICES OF THE DIVISION OF MINES
San Francisco (main office)
Los Angeles
Sacramento
Redding
BOUNDARIES OF THE DISTRICTS
OREGON
NEVADA
REDDING
SACRAMENTO
SAN FRANCISCO
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
MENDOCINO
NEVADA
YUBA
LAKE
COLUSA
SUTTER
PLACER
EL DORADO
YOLO
ALPINE
SONOMA
NAPA
AMADOR
SOLANO
SACRAMENTO
CALAVERAS
MARIN
SAN JOAQUIN
MONO
TUOLUMNE
CONTRA COSTA
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°


ECONOMIC MINERALS
FUELS
GAS DISTRICT
OIL & GAS DISTRICT
METALS
CHROMITE
COPPER
GOLD DISTRICT
IRON
MANGANESE
QUICKSILVER
SILVER
TUNGSTEN
ZINC-LEAD
NON-METALS
ANDALUSITE & KYANITE
BARITE
BUILDING STONE
SANDSTONE
GRANITE
SLATE
CLAY
DIATOMITE
GEMS
GYPSUM
IODINE
LIMESTONE, CEMENT, MARBLE
MAGNESITE
MICA
PUMICE
SALINES
SOAPSTONE
SULPHUR
TALC
WOLLASTONITE
SANTA CLARA
SANTA CRUZ
MERCED
MADERA
SAN BENITO
FRESNO
INYO
MONTEREY
TULARE
KINGS
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
LOS ANGELES
RIVERSIDE
ORANGE
SAN DIEGO
IMPERIAL
NEVADA
ARIZONA
MEXICO
37°
36°
35°
34°
33°

CONTENTS

3—70558

WALIBU QUICKSILVER MINE, KERN COUNTY, CALIFORNIA*

By Edgar H. Bailey ** and C. Melvin Swinney **
United States Department of the Interior, Geological Survey

OUTLINE OF REPORT

ILLUSTRATIONS

ABSTRACT

The Walibu (Cuddeback) quicksilver mine is in the southern part of the Sierra Nevada about 10 miles northwest of Tehachapi, Kern County, California. The deposit is of special interest as it lies outside the well-known belt of quicksilver deposits of the California Coast Ranges, but it is rather closely related to the western Nevada belt of deposits.

The ore, which contains cinnabar as the only economic mineral, is contained in one of several rhyolite dikes intruded along fractures in the granitic complex of the Sierra Nevada batholith. Ore bodies that have been mined were small, but a few of them were quite rich. The yield from intermittent operation since the discovery of the deposit in 1916 has been about 1,300 flasks of quicksilver.

Ore in sight when the property was examined early in 1943 probably could not be profitably mined even with wartime prices of about $200 a flask. However, the other rhyolite dikes in the district do not appear to have been carefully prospected, and perhaps other small rich ore bodies could be found by additional prospecting in them.

INTRODUCTION

The Walibu quicksilver mine, formerly known as the Cuddeback mine, is in the southern part of the Sierra Nevada in sec. 27, T. 31 S., R. 32 E., M.D. (see pl. 1). Lying about 30 miles east of Bakersfield and 10 miles northwest of Tehachapi, it is readily accessible by traveling over a mile of graveled road which branches northward from U. S. Highway 466 at the well-known Loop of the Southern Pacific Railroad. The principal workings are at an elevation of 3,400 feet above sea level in an area of moderately rugged hills supporting only sparse vegetation. Some snowfall in the winter hinders open-cut mining, but is insufficient to impede an underground operation.

* Published by permission of the Director, Geological Survey, U.S. Department of the Interior. Manuscript received for publication December 9, 1946.

** Geologist, U.S. Geological Survey.

FIGURE 1. Index map showing location of Walibu quicksilver mine, Kern County, California

As a part of the United States Geological Survey's wartime strategic mineral investigations the writers mapped the surface geology and accessible workings of the area during four days in January 1943, in order to determine the outlook for increased quicksilver production. Because no time was available for detailed laboratory study of the ores or thin sections of the rocks, the principal contributions of the work are the geologic maps included with this report.

The writers wish to acknowledge the friendly assistance during the examination of the property offered by the mine owner, Mr. W. F. Buass.

HISTORY AND PRODUCTION

The discovery of cinnabar, the only quicksilver mineral in the Walibu mine ore, was made at the site of the present workings in April 1916, by J. E. Hicks of Tehachapi.[1] He and W. N. Cuddeback began the development of the mine almost immediately, and by the end of the year had installed a 12-pipe Johnson-McKay retort and recovered 30 flasks of quicksilver. The following year the Cuddeback Cinnabar Company, headed by A. J. Blackley, leased the property and, using the same reduction equipment, recovered 250 flasks from near-surface ore.[2] During the 3 following years a continued production at about the same rate brought the total to 625 flasks, but in 1920, with the drop in the value of quicksilver following World War I, the mine was closed. In 1927 the property was leased to the Santa Ana Mining Company which, under the management of C. D. Holmes, did considerable underground development work, installed a small rotary furnace, and recovered by the end of 1931 nearly 500 flasks of quicksilver.[3] After several years of inactivity the property was taken over in 1936 by the Walibu Mining Company, which was largely owned by Mr. W. F. Buass of Keene, California, when the mine was examined early in 1943. This company overhauled the furnace and made some experimental attempts at concentrating the cinnabar using a small ball mill and a shaking table, but the annual production since they obtained the property has been small.

GENERAL GEOLOGY

The Walibu quicksilver deposit is of special interest to California miners and geologists because it is in the Sierra Nevada batholith outside the well-known belt of deposits in the California Coast Ranges. It is the southernmost of several deposits and occurrences of cinnabar that have been found along the eastern flank of the Sierra Nevada, at Coso Hot Springs [4] and near Markleeville [5] in California, and at Steamboat Springs [6] and Castle Peak [7] south of Reno, Nevada. The Walibu deposit is clearly more closely related to deposits lying along the belt extending northward through Nevada into central Oregon than to the more productive Coast Range deposits.

[1] Gillan, S. L., Cinnabar in the Sierra Nevada: Min. and Sci. Press, vol. 114, p. 79, 1917.

[2] Bradley, Walter W., Quicksilver resources of California: California Min. Bur. Bull. 78, p. 47, 1918.
Tucker, W. Burling, Kern County: California Min. Bur. Rept. 17, p. 314, 1920.

[3] Ransome, Alfred L., and Kellogg, J. L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, p. 380, 1939.

[4] Ross, Clyde P., and Yates, Robert G., The Coso quicksilver district, Inyo County, Calif.: U.S. Geol. Survey Bull. 936, pp. 395-416, 1943.

[5] Ransome, A. L., and Kellogg, J. L., op. cit., p. 371.

[6] Becker, G. F., Geology of the quicksilver deposits of the Pacific slope: U.S. Geol. Survey Mon. 13, pp. 331-353, 1888.

[7] Bailey, E. H., and Phoenix, D. A., Quicksilver deposits in Nevada: Univ. Nevada Bull., Geol. and Min. Ser., no. 41, pp. 184-186, 1944.

A northward-trending dike of rhyolite which has intruded a part of the granitic Sierra Nevada batholith contains the Walibu mine ore bodies (pl. 1). Other smaller dikes shown on the maps appear to be only slightly mineralized, but about 1½ miles east of the Walibu mine at the Fickert-Durnal mine another rhyolite dike has yielded a small amount of quicksilver. Possibly more prospecting in the other small rhyolite dikes in the area would disclose additional pockets of ore; certainly they should be regarded as the most favorable places for additional prospecting.

Rocks

Granitic Rock. The granitic rock which underlies most of the area mapped is a part of the complex of deep-seated igneous intrusions of late Jurassic age which forms the great Sierra Nevada batholith. No detailed geologic maps of the region near the mine are known to the writers, but the granitic rock is tentatively correlated with the Isabella granodiorite described by Miller[8] from an area a few miles to the north. In describing the formation Miller states that "The (Isabella) granodiorite grades, on the one side, into a granite, and on the other through quartz diorite into diorite" and that true granite is the least common facies. The main body of the rock shown on the map as "granitic rock" was identified in the field as quartz diorite, but it also contains large inclusions of mica and hornblende schists and other rocks formed by an intimate intermixing of igneous and sedimentary material. Both light- and dark-colored dikes cutting through the granitic rock are common. Although the granitic rocks of the region form bold outcrops, such outcrops are scarce in the immediate vicinity of the mine and detailed mapping of the complex there would be difficult if not impossible.

Rhyolite. The irregular rhyolite dikes which were probably intruded along fractures in the granitic rock are somewhat more resistant than the host rock and in most places crop out in low knobs. The largest dike, which contains all the known ore bodies, has a length of about 900 feet, and it probably attains a maximum width of about 250 feet near its northeastern end, although in this area the outcrops are so scattered that the dike may be multiple. Where the rhyolite is fresh and glassy it exhibits a pinkish groundmass with shiny transparent phenocrysts of quartz and orthoclase; however, some of it appears to be silicified and much of it is argillized to a chalky white rock in which the phenocrysts can be distinguished from the groundmass only with difficulty. In many places the rhyolite is stained reddish brown along cracks, but minerals containing iron are not abundant in the fresh rock. Sheeting and flow-banding are common in the rhyolite near its contacts, but the alteration tends to obscure these features.

In outcrop the contacts of the rhyolite generally appear to be vertical, but exposures in the mine workings indicate the northern contact of the large dike dips northward. The position of the flooded workings formerly reached through the No. 2 shaft suggests that near the surface the dike dips to the north at a low angle, whereas it is much steeper at a depth of 100 feet. The rock along the contacts is everywhere sheared and altered, and in several places many irregular slivers of

[8] Miller, W. J., Geologic sections across the southern Sierra Nevada of California: Univ. California Pub., Bull. Dept. Geol. Sci., vol. 20, p. 344, 1931.

granitic rock are contained in the dike close to its walls. Irregular small blocks of rhyolite in a rhyolitic groundmass along the margins of the dike doubtless are the result of brecciation during intrusion. It is not possible to be sure whether the clay alteration of the contact zone was a late phase of the intrusive cycle or an early phase of the cinnabar mineralization; however, the argillized zones seem to have controlled the deposition of the cinnabar and thus preceded the deposition of the ore mineral.

The age of the rhyolite intrusions cannot be determined in the immediate vicinity of the mine, nor are the writers aware of descriptions of similar rocks from nearby areas. Middle to late Tertiary age is suggested by the general sequence of volcanism in the Sierra Nevada province.

DESCRIPTION OF THE MINE AND ORE BODIES

Workings. The workings of the Walibu mine consist of several small glory holes and about 2,300 feet of drifts and small stopes which develop parts of the rhyolite dike through a distance of about 700 feet along its length (see pl. 1). The most extensive single working was reached through the No. 2 inclined shaft extending from the creek bottom at a point about 400 feet north of the furnace building, but it has been flooded for several years, and, according to reports, is probably mostly caved. Nearly all other workings were open when the property was examined in 1943 and the geology exposed in them, as well as the outline of the inaccessible workings, are shown on plate 2.

Ore Bodies. The ore bodies mined at the Walibu mine all lay in rhyolite close to the contacts with the granitic rock, and all contained cinnabar as the only ore mineral. The cinnabar, even in the ore bodies, is erratically distributed. Much of it encrusts fracture walls and fills small breccia veins having various attitudes, but to a smaller degree it is disseminated as minute crystals through the more altered rhyolite. Pyrite was reported to have been fairly abundant in the rich ore body reached through the flooded No. 2 shaft, but the ore encountered in the other workings contained little pyrite.

Statements about the features which resulted in the localization of the ore must be based on the apparent control for the smaller ore bodies explored by accessible workings, together with what can be inferred from the position of the inaccessible workings which developed the richest ore body. As stated above, the more important occurrence of cinnabar is as veinlets which fill irregular fractures in the rhyolite, but even though virtually all of the rhyolite is broken and fractured, only in a few areas are these fractures filled with cinnabar. Therefore the dominant control must have been exerted by structures which guided and perhaps also retarded the rising ore-bearing solutions. The clayey margins of the dike are the most obvious barriers to rising solutions, yet their mode of formation and the reason for their variation from place to place are somewhat obscure. The favored explanation for the localization of the ore requires the development of crushed zones along fractures in granitic rock prior to the intrusion of the rhyolite, and the areal map suggests that the shapes of the rhyolite dikes were determined by such fractures. Minor movements along the preexisting fractures following the intrusion are believed to have fur-

ther brecciated the dike margins and locally to have crushed the rhyolite which transected some of the old fractures. Solutions rising through this crushed rock that borders the dike and locally crosses it altered the crushed rock to form the clayey gouge which was effective in guiding the ore-bearing solutions.

The richest ore body is believed to have been localized under the flattest part of a clay-lined inclined inverted trough formed by the intersection of two northward-dipping fractures which meet north of the No. 2 shaft. The probable continuation of these broken zones is suggested by the two canyons which join over the workings, but no indication of their existence was found in the few scattered exposures in the area. The only other rich ore body, designated the Taylor ore body on plate 2, was a small one, now seemingly exhausted, which apparently lay near the intersection of several of the major pre-rhyolite fractures. Lower-grade ore bodies mined from the glory holes appear to have contained scattered cinnabar deposited from solutions migrating upward and spreading outward from the margins of the dike; perhaps the lack of any clear-cut structural control accounts for the widespread distribution but low grade of these ores.

OUTLOOK

The first ore that was retorted contained several percent of quicksilver, and that mined through the shaft is reported to have averaged more than 10 pounds of quicksilver to the ton. Ore containing 7 or 8 pounds of quicksilver to the ton is said to have been in sight on the 108-foot level when the mine was flooded, but without additional information about its extent, it would appear hazardous to reopen the caved shaft to mine it. However, the more disseminated ore mined in the glory holes was doubtless of a considerably lower grade as is indicated by the ore remaining in the walls and as is suggested by the attempts to concentrate the cinnabar mechanically before retorting. It would appear to be very risky to attempt to mine any of the ore that was in sight when the property was examined in 1943 even with a price of as much as $200 a flask, but the fact that small rich ore bodies have been found should encourage further examination of the rhyolite dikes of the surrounding area.

MINES AND MINERAL RESOURCES OF LAKE COUNTY, CALIFORNIA

By Charles V. Averill *

OUTLINE OF REPORT

ILLUSTRATIONS

GENERAL DESCRIPTION OF THE COUNTY

Geography

Lake County lies due north of San Francisco at a distance by road of 100 miles. Mendocino County, which is about 40 miles wide, lies between Lake County and the Pacific Ocean. Lakeport on the shore of Clear Lake is the county seat and the largest town. Upper Lake, Kelseyville, Lower Lake, and Middletown are smaller towns in the Clear Lake vicinity. The total population of the county by the 1940 census was 8,069 persons. The land area is 1,256 square miles.

Topography

Clear Lake, a body of fresh water 19 miles long and 2 to 8 miles wide, with a maximum depth of 50 feet, lies near the center of the county. This lake now occupies part of a basin that was formerly

* Mining Engineer, California State Division of Mines, Ferry Building, San Francisco. Manuscript submitted for publication October 10, 1946.

drained by two streams, Cold Creek, flowing westward to the Russian River, and Cache Creek, flowing eastward to the Sacramento River.[1] Cache Creek was crossed near its gorge entrance by a small lava flow, but later a landslide cut off Cold Creek and caused the water of Clear Lake to rise higher than the surface of this lava flow. Thus drainage to the Sacramento River was reestablished, but drainage to the Russian River is now cut off. The Blue Lakes occupy parts of the gorge through which the basin of Clear Lake was formerly drained by Cold Creek. The more mountainous northern part of the county is drained by Eel River. Elevations range from 1,340 feet above sea level at Clear Lake to over 7,000 feet at Snow Mountain.

Climate

The climate is mild, without extremes of either heat or cold; and falls of snow are common only at the higher elevations. Annual rainfall is about 35 inches. The pleasing summer climate and the attractive mountain and lake scenery draw many people to the numerous summer resorts. Hunters and fishermen also find the climate and the mountains, lakes, and streams much to their liking.

Transportation

Lake County has no railroad service and is dependent entirely on state highways, county, and private roads for transportation. Winding over the mountain at an easy grade, a good highway crosses Mount St. Helena on the southern county line, and connects Calistoga, the railroad terminus in Napa County, with Middletown, Lake County. A similar highway connects Lakeport with Hopland to the west. A still better highway with easier grades connects Ukiah, Mendocino County, with Upper Lake, runs along the north shore of Clear Lake, thence to Williams in the Sacramento Valley. This is a part of the Ukiah-Tahoe state highway. A number of other all-weather roads reach such points as Kelseyville and Lower Lake, but many other points are reached only by means of graveled or dirt roads. Small boats are operated between points on the shore of Clear Lake, chiefly for pleasure.

Industries

Agriculture is the main industry in Lake County. Bartlett pears, walnuts, almonds, prunes, apples, grapes, and olives are important; and oranges, figs, berries, melons, and other fruits are grown. Other important crops are wheat, barley, corn, oats, beans, alfalfa, and hops. The livestock industry flourishes, the higher mountains furnishing abundant summer range, the foothill country and alfalfa fields taking care of the stock in the winter. Practically all of Lake County north of Clear Lake is in the California National Forest, which extends northward into the southern part of Trinity County. In this entire forest are 4,000,000,000 feet of pine and fir timber on government land, and 2,000,000,000 feet on private land. Chamiso brush occurs in dense stands in this forest up to elevations of 3,500 and 4,000 feet. Above this are fine stands of pine and fir. Extensive areas of scrub white oak are characteristic of the region. The mature government timber is available for sale under competitive bids; but, on account of the lack of suitable transportation within the

---

[1] Davis, William Morris, The lakes of California: California Div. Mines Rept. 29, pp. 197-200, 1933.

forest, no large sales have been made. The forest is the best stocked deer region in California, and is a favorite with sportsmen. The Columbian black-tail deer abound in the brush as well as in the timber belt.

The summer-resort business is a thriving one in Lake County. The mineral springs with their hotels and baths form one type of resort; the lake resorts with fishing, swimming, and boating make up a second type; and the mountain camps with their attractions of hunting and fishing form a third type. Several tracts of land near Clear Lake have been subdivided into lots and sold as sites for summer homes.

GEOLOGY AND MINERAL DEPOSITS

The geologic map of California [2] shows that Franciscan (Jurassic) sediments predominate in Lake County. They have been intruded by large dikes of ultrabasic rocks now altered to serpentine. The volcanic rocks in the vicinity of Clear Lake form a prominent feature of the geology. They have been described in detail by Anderson [3] who has also published a detailed map of the volcanic rocks south and east of Clear Lake.

Minerals of commercial importance are associated with the igneous rocks. A little chromite and manganese ore has been produced, but the important production has been that of quicksilver; and high prices during the war of 1941-45 stimulated production of that liquid metal. Late in 1945, production of quicksilver was much lower because of declining prices. Mineral springs continue to be of importance both as sources of water for bottling and as centers of attraction for resorts.

Asbestos

Copsey and Jones prospect is owned by Arthur Copsey of Middletown and Herbert Jones of Lakeport. It is located about 1½ miles south of Howard Springs at a distance of about 10 miles from Middletown by the Big Canyon road. The Johns-Manville Company is said to have done a few hundred feet of development work on the deposit and to have taken out 7 or 8 tons of asbestos early in 1928. The property has been idle recently.

Barite

In the museum of the Division of Mines is a specimen of barite, said to have come from an undeveloped deposit near Glenbrook.[4]

Borax[5]

Borax was at one time produced from Borax Lake, 8 miles west of north from Lower Lake, and 2 miles south of Sulphur Bank mine. Commercial production was made from 1864-68 by the California Borax Company. For analysis of water of Borax Lake, see section on *soda*. Little Borax Lake, 4 miles west of Borax Lake, on the opposite side of Clear Lake, also produced some borax in 1872.

---

[2] Jenkins, Olaf P., Geologic map of California, scale 1:500,000: California Div. Mines, 1938.

[3] Anderson, Charles A., Volcanic history of the Clear Lake area, California: Geol. Soc. America, Bull. 47, pp. 629-664, 6 pls., 8 figs., 1936.

[4] Aubury, Lewis E., The structural and industrial minerals of California: California Min. Bur. Bull. 38, p. 360, 1906.
Bradley, Walter W., Lake County: California Min. Bur. Rept. 14, p. 204, 1916.

[5] Hanks, Henry G., Report on the borax deposits of California and Nevada: California Min. Bur. Rept. 3, pt. 2, pp. 14-26, 78, 79, 1883.
Hanks, Henry G., Catalogue and description of the minerals of California as far as known, with special reference to those having an economic value: California Min. Bur. Rept. 4, p. 91, 1884.
[5] —Continued on page 19.

Mineral production of Lake County, 1873-1945

Year	Quicksilver		Mineral water		Chromite		Miscellaneous stone,[1] value	Miscellaneous and unapportioned		
	Flasks	Value	Gallons	Value	Tons	Value		Amount	Value	Substance
1873	880	$70,790	--------	--------	------	------	--------	--------	--------	
1874	1,695	178,280	--------	--------	------	------	--------	--------	--------	
1875	8,821	743,287	--------	--------	------	------	--------	--------	--------	
1876	14,199	624,756	--------	--------	------	------	--------	--------	--------	
1877	18,100	675,130	--------	--------	------	------	--------	--------	--------	
1878	14,428	474,681	--------	--------	------	------	--------	--------	--------	
1879	15,582	309,303	--------	--------	------	------	--------	--------	--------	
1880	17,148	531,588	--------	--------	------	------	--------	--------	--------	
1881	17,393	518,833	--------	--------	------	------	--------	--------	--------	
1882	10,193	287,748	--------	--------	------	------	--------	--------	--------	
1883	6,481	186,329	--------	--------	------	------	--------	--------	--------	
1884	4,182	127,551	--------	--------	------	------	--------	--------	--------	
1885	4,765	146,524	--------	--------	------	------	--------	--------	--------	
1886	3,498	124,179	--------	--------	------	------	--------	--------	--------	
1887	4,307	182,509	--------	--------	------	------	--------	--------	--------	
1888	6,636	282,030	*	*	------	------	--------	--------	--------	
1889	4,713	212,085	*	*	------	------	--------	--------	--------	
1890	4,232	222,180	*	*	------	------	--------	--------	--------	
1891	4,975	225,119	*	*	------	------	--------	--------	--------	
1892	11,140	453,509	*	*	------	------	--------	--------	--------	
1893	9,731	357,614	*	*	------	------	--------	--------	--------	
1894	12,471	382,954	*	*	------	------	--------	--------	--------	
1895	12,856	465,074	87,500	$42,000	------	------	--------	--------	--------	
1896	6,307	232,484	65,920	32,460	------	------	--------	--------	--------	
1897	3,585	134,546	511,950	76,585	------	------	--------	--------	--------	
1898	1,729	64,746	523,000	37,350	------	------	--------	--------	--------	
1899	2,954	128,179	166,020	75,924	------	------	--------	--------	--------	
1900	3,165	127,345	758,600	45,400	------	------	--------	--------	--------	
1901	4,395	211,324	201,706	120,360	------	------	--------	--------	--------	
1902	3,611	161,568	241,100	126,663	------	------	--------	--------	--------	
1903	2,595	106,397	381,040	187,621	------	------	--------	--------	--------	
1904	[2]2,854	109,719	659,000	221,000	------	------	--------	--------	--------	
1905	1,462	51,937	489,000	219,500	------	------	--------	--------	--------	
1906	1,066	38,909	365,000	160,000	------	------	--------	--------	--------	
1907	802	30,604	304,340	130,936	------	------	--------	--------	--------	
1908	1,300	54,951	246,545	118,300	------	------	$10,000	--------	--------	
1909	1,075	56,277	265,000	108,270	------	------	--------	--------	$28,423	Unapportioned, 1900-09.
1910	1,048	47,422	212,546	95,005	------	------	--------	--------	--------	
1911	899	41,363	227,440	58,933	------	------	--------	--------	--------	
1912	209	8,786	202,000	114,500	------	------	--------	--------	--------	
1913	395	15,891	209,750	109,938	------	------	--------	--------	--------	
1914	331	16,236	254,150	47,267	------	------	--------	--------	--------	
1915	492	41,660	165,130	24,371	------	------	5,000	--------	1,503	Copper, gold, silver.
1916	1,139	106,496	195,650	54,160	871	$15,070	4,500	--------	770	Other minerals.
1917	1,067	107,071	129,157	22,685	1,466	36,326	2,500	85 tons --------	1,900 70	Manganese. Other minerals.
1918	1,540	172,173	87,067	15,006	476	24,790	1,000	--------	2,907	Manganese and natural gas.
1919	229	20,604	62,839	17,471	[3]	------	1,200	--------	100	Other minerals.
1920	385	24,314	43,693	16,413	84	1,560	13,200	247 tons --------	7,816 250	Manganese. Other minerals.
1921	22	880	54,715	26,751	------	------	146,508	--------	250	Other minerals.
1922	38	2,000	60,420	29,370	------	------	16,669	--------	250	Other minerals.
1923	17	1,050	63,730	44,738	------	------	55,000	--------	250	Other minerals.
1924	[3]	--------	66,420	59,423	------	------	22,833	--------	14,140	Natural gas and quicksilver.
1925	--------	--------	62,970	57,793	------	------	15,300	--------	255	Copper and natural gas.
1926	86	7,778	57,000	58,235	------	------	[3]	--------	9,680	Natural gas and miscellaneous stone.
1927	245	29,234	45,643	51,149	------	------	4,445	440 M cu.ft.	220	Natural gas.
1928	1,206	145,718	123,500	22,750	------	------	19,395	1,000 M cu ft. --------	500 740	Natural gas. Other minerals.
1929	1,697	203,247	30,956	22,100	------	------	154,200	--------	8,153	Gems, natural gas.
1930	1,760	195,710	36,758	14,524	------	------	58,059	--------	71	Other minerals.
1931	3,046	251,879	24,916	14,034	------	------	14,785	--------	70	Other minerals.
1932	1,038	57,850	18,870	6,050	------	------	33,164	--------	20	Other minerals.
1933	1,610	90,592	11,799	11,177	------	------	32,052	--------	30	Other minerals.
1934	3,497	221,837	11,372	11,005	------	------	27,426	--------	213	Other minerals.
1935	4,097	285,426	22,410	13,909	------	------	21,315	-------- --------	65 35	Gold. Other minerals.

Mineral production of Lake County, 1873-1945—continued

Year	Quicksilver		Mineral water		Chromite		Miscellaneous stone,[1] value	Miscellaneous and unapportioned		
	Flasks	Value	Gallons	Value	Tons	Value		Amount	Value	Substance
1936	3,795	292,571	29,729	12,545	-------	-------	35,929	----------	21	Other minerals
1937	4,012	341,444	38,489	33,858	-------	-------	17,258	----------	25	Other minerals.
1938	3,718	265,430	26,560	12,770	-------	-------	2,898	----------	----------	
1939	4,155	416,150	23,850	7,100	-------	-------	28,290	----------	35	Other minerals.
1940	4,966	845,592	20,588	10,902	-------	-------	27,883	----------	50	Other minerals.
1941	6,053	1,045,726	9,957	4,635	-------	-------	41,447	----------	75	Other minerals.
1942	4,216	792,438	9,100	1,800	-------	-------	37,591	----------	883	Manganese ore, natural gas.
1943	4,206	774,813	8,625	3,073	[3]	-------	15,415	----------	5,080	Chromite, manganese ore.
1944	3,781	430,317	7,185	2,956	-------	-------	30,735	----------	4,381	Other minerals.
1945	1,448	180,776	8,700	2,012	-------	-------	14,660	----------	----------	
Totals	311,769	16,771,513	7,929,405	$2,812,777	2,897	$77,746	$910,657	----------	$89,231	

* Bartlett Springs since 1888 and Witter Springs since 1899 reported to U. S. Geological Survey, but no segregated figures available for Lake County previous to 1895.

[1] Includes crushed rock, rubble, rip-rap, sand, gravel.

[2] Flasks of 76½ pounds previous to June, 1904; of 75 pounds thence, through 1927; of 76 pounds since January, 1928.

[3] See under 'Unapportioned.'

In addition to the above, Lake County has produced the following:

Borax	Sulphur	Pounds	Value
1864 to 1868 Borax Lake yielded 590 tons refined borax, worth $414,636; 1872 from Lake Hachinhama, 140 tons, worth $89,600; total 730 tons, worth $504,236.	1865	214,650	$8,030
	1866	675,963	21,970
	1867	487,603	13,420
	1868	503,481	10,080
	Totals	1,881,697	$53,500

Carbon Dioxide

Bartlett Springs Company. Bartlett Springs, via Williams, utilizes carbon dioxide gas from a spring on the property to recarbonate mineral water for sale. Carbon dioxide issues from other springs on the property, and this has been considered for the manufacture of dry ice, but no plant has yet been installed.

Other Occurrences. Carbon dioxide has been reported near Kelseyville and at other points in Lake County, but it remains undeveloped.

[5] (Cont.)

Hanks, Henry G., California minerals: California Min. Bur. Rept. 6, pt. 1, p. 94, 1886.

Irelan, Wm. Jr., Lake County: California Min. Bur. Rept. 8, p. 326, 1888.

Goodyear, W. A., Lake County: California Min. Bur. Rept. 10, pp. 237, 243, 269, 1890.

Crawford, J. J., Mines and mining products of California: California Min. Bur. Rept. 12, p. 34, 1894.

Crawford, J. J., Borax: California Min. Bur. Rept. 13, p. 46, 1896.

Bradley, Walter W., Lake County: California Min. Bur. Rept. 14, p. 204, 1916.

Vonsen, M., and Hanna, G. D., Borax Lake, California: California Jour. Mines and Geology, vol. 32, pp. 99-108, 5 figs., 1936.

Bailey, Gilbert E., The saline deposits of California: California Min. Bur. Bull. 24, pp. 51-52, 1902.

Whitney, Josiah Dwight, Geological survey of California; Geology, 1, p. 98, 1865.

Becker, G. F., Geology of the quicksilver deposits of the Pacific slope, with an atlas: U.S. Geol. Survey Mon. 13, pp. 244, 264-268, 1888.

Browne, John Ross, and Taylor, James W., Reports upon the mineral resources of the United States: U.S. Treasury Dept., pp. 179-187, 1867.

Browne, John Ross, Report on the mineral resources of the States and Territories west of the Rocky Mountains: U.S. Treasury Dept., pp. 264-266, 1868.

Chromite

The chromite properties listed in the following table are in Lake County.[6]

Chromite deposits in Lake County, California

Name	Owner	Location Sec.	T.(N)	R.(W)
Betwixt (E.Z.)	P. B. Edwards, G. B. Smith, Lower Lake (1918)	30	12	5
Black Bart (Great Western)	W. B. Shepherd, Monticello (1942)	16	10	7
Black Diamond	(see Smyth)	------	------	------
Bottle Rock	(see Young Adams)	------	------	------
Brown	J. H. Brown, Cobb	29	12	8
Butler	W. E. and Theresa Butler, Middletown	24	10	6
Copsey	Arthur Copsey, Middletown	4	11	7
		33	12	7
E.Z. (see Betwixt)		29	12	5
Glad I Found It		24 (?)	10	6
Gordon Springs	Irene Anderson, San Francisco; Laura Miles, Petaluma (1918)	2	11	8
Great Western	(see Black Bart)	------	------	------
Gunn	J. A. Gunn, Kelseyville	11, 14	12	9
Harp & Sons ranch	Harp & Sons (1918)	20	11	7
Herman	(see Smyth)	------	------	------
Holmstedt	Victor Holmstedt and Van Warner, Middletown	22	10	7
Kangaroo Court	C. L. Russell, Middletown; E. L. Wilkinson, Calistoga (1918)	25	10	7
Lucky Strike	W. B. Shepherd, Monticello (1942)	13, 24	12	6
Manzanita	(see Copsey)	------	------	------
Mastick ranch		3	10	6
Mint	(see Copsey)	------	------	------
Popp and Nichelini	William Nichelini and F. W. Popp, Calistoga (1918)	13	12	8
Red Devil	Sawyer Tanning Co., lessee (1917)	8 (?)	12	5 (?)
Riverside	(see Betwixt)	NW 29	12	5
Schaffer	F. Schaffer, Kelseyville	36	13	9
Smythe (Herman)	August Herman and Tom Smythe	28	11	5
Sutro	Charles Sutro, San Francisco (1918)	26	10	7
Uncle Josh	(see Copsey)	------	------	------
Whispering Pines	David Streckler	14	11	8
Young Adams	Young Adams	12	12	9

Chromite float has been found in sec. 35, T. 14 N., R. 7 W., and abandoned prospects are known in the SW¼ sec. 33, T. 12 N., R. 5 W. and the NE¼ sec. 3, T. 11 N., R. 5 W. Until the end of 1943, the properties mentioned above had produced only 13 tons of chrome ore during the war of 1941-45, in spite of high prices offered. Information on the Hull Mountain Lode and Smaker property was obtained in 1945.

Hull Mountain Lode consists of four unpatented claims in sec. 26 (?), T. 19 N., R. 10 W., M. D., near Lake Pillsbury, held by Dave Dondero, Lakeport, and A. M. Akins, Lower Lake. Shipments of 60 tons were made in 1944, and 25 tons were mined but not shipped in 1945. Mining has been done by stripping, but Dondero states that a lens now exposed,

[6] Dow, D. H., and Thayer, T. P., Chromite deposits of the northern Coast Ranges of California: California Div. Mines Bull. 134, pt. 2, pp. 1-38, 2 figs., 1946.

which will require underground mining, is producing one ton of chrome ore for each foot of depth. Other prospects of ore of good grade occur on the property; also considerable low-grade ore. The following analysis was furnished by Akins.

Cr_2O_3—43.17%
SiO_2 — 7.40
Fe —10.43
P — 0.002
S — none

Smaker Property. Jack Smaker has shipped chrome ore from a property 5 miles northwest of Bartlett Springs, now held by Mary Smaker, Clear Lake Oaks. The following analysis was furnished by A. M. Akins of Lower Lake:

Cr_2O_3—52.91%
SiO_2 — 3.60
Fe —10.21
P — 0.069
S — 0.12
Chromium to iron ratio: 3.54 to 1.

Diatomite

Diatomite occurs on the S-Bar-S ranch in sec. 27, T. 13 N., R. 8 W., M. D., assessed to Rae P. Williams, Kelseyville (?), and on the next property to the east. It is found on both sides of a road running northward to Konokti Bay where the road crosses Thurston Creek. A few hundred feet west of the road, the diatomite outcrops where it has been eroded by the creek for a thickness of several feet. A little farther to the west, it is seen in a dry well said by local residents to be 100 feet deep, and entirely in diatomite. To the east of the road at a distance of a few hundred feet is a drilled well said to be 250 feet deep, and entirely in diatomite. Information on this deposit was furnished by A. H. Hoyt of Kelseyville, and others. A sample taken by the writer from the exposure on Thurston Creek was identified in the laboratory of the Division of Mines.

Magnesite

Dow Property. A large deposit of magnesite is said to occur on the property of Caryl Dow of Clear Lake Oaks between Wolf Creek and North Fork Cache Creek, sec. 12, T. 14 N., R. 7 W., M. D. The following analysis was furnished by A. M. Akins of Lower Lake:

SiO_2— 0.44%
Fe_2O_3— 1.62
Al_2O_3— 0.41
$CaCO_3$— 5.26
$MgCO_3$—91.41

Manganese

Gravelly Valley manganese mine is in sec. 3, T. 18 N., R. 10 W., M. D., about 1 mile west of Lake Pillsbury and about 35 miles by road from Ukiah. A non-responsibility notice posted on the property in 1945 indicated that the ground is held by Ed. George and others. This is the only manganese mine in Lake County that has produced during the war period. About 1943, several carloads of manganese ore were sold to Metals Reserve Company by Toy L. Young, who held a lease on the property.

Black oxides of manganese occur in lenses about 3 feet wide in Franciscan chert. The manganese ore is siliceous, and hand-sorting is needed to produce a commercial grade. Probably more than 50 percent of the material mined from the lenses must be discarded during the sorting process. The property was idle in 1945. Other occurrences of manganese in Lake County are mentioned in Division of Mines Bulletin 125, *Manganese in California.*

Mineral Paint

Immel Property. A few shipments of iron oxide for paint were made from this property in sec. 36, T. 13 N., R. 9 E., M. D., about 1920. No shipments have been made recently.

Mineral Springs

Adams Springs are in sec. 26, T. 12 N., R. 8 W., M.D., 7 miles southwest of Lower Lake and 30 miles north of Calistoga. They were first taken up by Charles Adams in 1872; but since 1888 they have been owned by the Prather family of Adams Springs postoffice. A resort to accommodate about 500 persons is maintained in this beautiful wooded country, in the canyon at the head of Putah Creek at an elevation of about 3,000 feet. The timber is pine, fir, and oak.

Allen Springs are in secs. 7 and 8, T. 15 N., R. 7 W., M.D., in the canyon of Bartlett Creek, 3 miles below Bartlett Springs on the Williams-Bartlett road. Numerous springs issue from the bed and side of the creek: White Sulphur, Soda, Soda and Iron, and others. No improvements have been added recently.

Anderson Springs are in sec. 25, T. 11 N., R. 8 W., M.D., 6 miles northwest of Middletown and 24 miles north of Calistoga, in the timbered section of southwestern Lake County. Eight springs have been utilized, but there are several others. Both cold and warm springs occur, the names of some of them being: Iron, Sour, Magnesia, Hot Sulphur and Iron, Iron and Magnesia, and Steam Bath. The last two named give off hydrogen sulphide. Epsom and Glauber salts are found in some of the springs, also traces of chromium. About a dozen cabins are maintained here for resort purposes. A. R. Maede of Middletown is the owner.

Bartlett Springs are in sec. 2, T. 15 N., R. 8 W., M.D., 42 miles west of Williams. The road passes the springs at an elevation of 2,350 feet, then continues to Upper Lake and Lakeport after crossing a summit at an elevation of 4,040 feet. The hotel formerly operated here has burned, and only a few cabins are maintained together with facilities for bottling the water for sale. Bartlett Springs Company of Bartlett Springs, via Williams, is the owner.

Behr Soda Springs are in sec. 10, T. 13 N., R. 8 W., M.D., on the edge of Clear Lake, 5 miles east of Kelseyville, and are owned by Mrs. Ethel Dean of Redding. No improvements have been made.

Blue Lakes Springs are in sec. 6, T. 15 N., R. 10 W., M.D., 18 miles east of Ukiah. A sulphur spring and an iron spring occur on the property, which is owned by Renee A. Malpas of Midlake (a summer postoffice) and others.

Bonanza Springs are in sec. 30, T. 12 N., R. 7 W., M.D., between Siegler and Howard Springs, 5 miles southwest of Lower Lake and 2 miles east of Adams Springs. A large hotel operated here was destroyed by fire, and no improvements have been made recently. Cool springs of several different kinds occur here. The present owner is Edward Stahl, 1600 Market Street, San Francisco.

Castle Springs (Mills, Noble's) in sec. 26, T. 11 N., R. 8 W., M.D., 7 miles northwest of Middletown, are owned by the Salvation Army. Buildings have burned, and the property is not being used. The Big Hot Sulphur Spring flows about 40,000 gallons of water (163° F.) per 24 hours. Several smaller springs are on the property.

Complexion Springs are in sec. 10, T. 15 N., R. 6 W., M.D., on the Williams-Bartlett road, near the eastern boundary of the county, and are utilized only by campers. The water has a milky appearance and contains sodium chloride and ammonia.

Dinsmore Springs (soda and iron), in sec. 11, T. 14 N., R. 7, W., M.D., are owned by Caryl Dow of Clear Lake Oaks. Nothing has been done with them recently.

Dollar Springs (Warm Springs) are in sec. 8, T. 11 N., R. 5 W., M.D., on Black Mountain, 11 miles northeast of Middletown, and are owned by B. Norman of Middletown. The owner sells water from these springs..

Grizzly Medical Springs (Richardson's) are in sec. 3, T. 13 N., R. 6 W., M.D., 5 miles west of Sulphur Creek, which is in Colusa County. S. G. Mason of Clear Lake Oaks sells water from them.

Harbin Hot Springs are in sec. 20, T. 11 N., R. 7 W., M.D., 3½ miles northwest of Middletown and 20 miles north of Calistoga. The owner is N. S. Booth of Middletown. Hot sulphur, iron, magnesia, and cold white sulphur springs, and a large fresh-water spring occur here. A resort is operated by the owner.

Hazel Springs (Dennison) are in sec. 26, T. 16 N., R. 9 W., M.D., 6 miles northeast of Upper Lake. They have recently been sold by Ruth J. Misch, c/o Amos Ogden, Upper Lake. These springs are reached by trail, and are used only by campers.

Highland Springs include a number of springs in sec. 31, T. 13 N., R. 9 W., M.D., 13 miles east of Pieta, a railroad station in Mendocino County. Temperatures range from 60° to 80° F., and carbon dioxide is given off by some of the springs. A resort was formerly operated but the property is now being improved by Dr. Neal C. Woods of Lakeport as a home only.

Hough Springs are in sec. 10, T. 15 N., R. 7 W., M.D., 8 miles east of Bartlett Springs on the road to Williams, and on the north fork of Cache Creek. There are several springs of different kinds, the soda spring giving a water heavily charged with carbonic-acid gas. The resort consists of a hotel, cottages, and tents. George F. Abel of Williams is the owner. The property is now used as a sheep ranch.

4—70558

Howard Springs are in sec. 30, T. 12 N., R. 7 W., M.D., 7 miles southwest of Lower Lake or 14 miles northwest of Middletown. About 40 different springs range in temperature from 65° to 110° F. A resort is operated by J. P. Francisco of Middletown, who features hot baths.

Newman Spring is in sec. 35, T. 16 N., R. 8 W., M.D., $1\frac{1}{2}$ miles north of Bartlett Springs. It is owned my Werner C. Foss, 1021 5th Avenue, San Mateo. The water contains borax. No resort is operated here.

Paramore Spring in sec. 21, T. 17 N., R. 9 W., M.D., north of Upper Lake near the Rice Fork of Eel River is operated as a cattle ranch. The owner is Stonewall Smith, R. 2, Box 146, Los Gatos.

Roaring Soda Spring (Morton) is in sec. 15, T. 18 N., R. 10 W., M.D., near Hullville, and is owned by the estate of J. M. Macdonough, c/o Baldwin and Howell, 318 Kearny Street, San Francisco. Campers occasionally use the spring.

Royal Spring is in sec. 7, T. 16 N., R. 8 W., M.D., and is owned by Martha E. Holway of Colusa.

Saratoga Springs (Pierson) are in sec. 4, T. 15 N., R. 10 W., M.D., 22 miles east of Ukiah or 6 miles west of Upper Lake. They are owned by Mrs. E. R. (Bertha) Keil of Witter Springs postoffice. A resort consisting of hotel, cottages, and swimming tank is maintained; and amusements are provided.

Seigler Springs are in sec. 24, T. 12 N., R. 8 W., M.D., and are owned by Hoberg Bros. and Olsen of Hobergs postoffice. A resort for 400 to 500 persons is maintained. Facilities include hotel, cottages, dance hall, and swimming pool. The springs range in temperature from 64° to 126° F., and some of them are utilized to provide hot baths.

Soda Bay Springs are in sec. 6, T. 13 N., R. 8 W., M.D. A resort was formerly maintained here, but the land has been subdivided and sold as lots. The springs are used for baths.

Spring Hill Farm Resort is in sec. 8, T. 10 N., R. 7 W., M.D., near Middletown, and is owned by L. S. Peterson of Middletown. A small iron and magnesia spring occurs here.

Sulphur Bank (see under *Quicksilver*).

Witter Springs are in sec. 5, T. 15 N., R. 10 W., M.D., 7 miles west of Upper Lake and 12 miles east of Ukiah. The water has a high mineral content of 1019 grains per gallon and is bottled for sale. The operator is W. E. Whitaker, 1265 4th Avenue, San Francisco 22.

Natural Gas

At Kelseyville, sec. 14, T. 13 N., R. 9 W., M.D., methane was struck in a well at a depth of 158 feet on land owned by W. Renfro and others. This gas is now used as fuel in a fruit-dehydrator owned by Henry Mauldin, Lakeport. For some types of fruit, the gas is sufficient to keep the dehydrator in operation, but other types require more heat, and fuel-oil is used in addition to the gas. Methane is collected at Thurston Lake by R. D. Frye and used for domestic purposes. This lake is in sec. 31, T. 13 N., R. 7 W., M.D., and adjoining sections. Its area is less

than 1 square mile. The gas rises through the water and may be seen as bubbles on the surface.

Quicksilver

Abbott mine[7] is in the NW¼ sec. 32, T. 14 N., R. 5 W., M.D., near the eastern county line of Lake County and about 3 miles by road southwest of Wilbur Springs.

The Abbott mine is a famous old mine of Lake County, having been discovered in 1862. It was operated from 1870-79, and later on a large scale from 1889-1906 by Empire Consolidated Quicksilver Mining Company. Total production was over 30,000 flasks. R. A. Boggs acquired the property and operated during 1916-17. Production for the next 2 years came from cleaning up around a 48-ton Scott furnace. A few flasks production were reported by Theodore Smith in 1927. In 1939 the property was owned by Mrs. Barber DeBles of Williams, who reported a few flasks obtained by cleaning up a Scott furnace in 1938. E. Freels reported a few flasks production in 1939. In 1940 the property was purchased by International Metals Development Company, Hoge Building, Seattle, Washington. C. O. Reed, care of the Abbott mine, Williams, California, is manager for this company, and George Thompson is foreman.

The International Metals Development Company has sunk a shaft from the 200-foot level to the 500-foot level since 1942. Mining was proceeding on the 400- and 500-foot levels in 1945. A lens of ore about 100 feet long by 10 feet thick has been mined from the 200-foot to the 500-foot level. This lens has an eastward-trending strike and a dip roughly 55° S., but it is very irregular in dip, in strike, and in thickness. The hanging wall is shale, and the footwall is serpentine. Slight seepages of petroleum are occasionally encountered in the wall rocks.

A furnace-plant, capacity 40 tons per 24 hours, was being operated continuously in the summer of 1945. It is a rotary kiln 50 feet long by 40 inches in diameter inside the fire-brick lining. The fumes go from the furnace to a cyclone dust collector, then through a 7½-horsepower suction fan to the condenser consisting of 33 stands of cast iron pipe each 18 feet long by 12 inches in diameter. Water is sprayed on the outside of these pipes to condense the quicksilver.

Anderson mine[8] is in the SW¼SW¼ sec. 25, T. 11 N., R. 8 W., M.D., in the heart of the Mayacmas district at Anderson Springs about 4 miles west of Middletown.

---

[7] Watts, W. L., Lake County—the Abbott quicksilver mines: California Min. Bur. Rept. 11, pp. 239-240, 1893.
Crawford, J. J., op. cit., 1894, p. 360.
Crawford, J. J., Quicksilver: California Min. Bur. Rept. 13, p. 595, 1896.
Bradley, Walter W., Lake County: California Min. Bur. Rept. 14, p. 229, 1916.
Huguenin, E., and Castello, W. O., Lake County: California Min. Bur. Rept. 17, p. 81, 1921.
Averill, Charles Volney, Lake County: California Div. Mines and Mining, Rept. 25, p. 351, 1929.
Ransome, Alfred L., and Kellogg, John L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, p. 384, 1939.
Forstner, William, The quicksilver resources of California: California Min. Bur. Bull. 27, p. 46, 1903.
Bradley, Walter W., Quicksilver resources of California, with a section on metallurgy and ore-dressing: California Min. Bur. Bull. 78, p. 53, 1918.

[8] Huguenin, E., and Castello, W. O., Lake County: California Min. Bur. Rept. 17, p. 81, 1921.
Averill, Charles Volney, Lake County: California Div. Mines and Mining, Rept. 25, p. 351, 1929.
Forstner, William, The quicksilver resources of California: California Min. Bur. Bull. 27, p. 48, 1903.
Bradley, Walter W., Quicksilver resources of California, with a section on metallurgy and ore-dressing: California Min. Bur. Bull. 78, p. 55, 1918.

Howard H. Barrows, 1648 16th Street, Oakland, California, has purchased the southern 12 acres of the quarter-quarter section mentioned above, a tract 1,320 by 400 feet to combine with the Big Chief and Thorne mines as a group. The ore body is the same as that on the Big Chief, and further details will be found herein under that heading. The following description of the Anderson mine is by Ransome and Kellogg.[9]

Quicksilver deposits were first noted in this vicinity prior to 1917. Nevertheless, it was not until 1929 that any exploration or development was done. At that time E. N. Schwartz, of Lakeport, came across an outcrop in the creek bed a short distance below the resort at the springs. He proceeded to sink a small prospect hole, and by 1929 had installed a 12-pipe retort. Schwartz recovered a few flasks in 1929, but operations were not continued. Operation of the property was resumed by Schwartz in 1932, and continued through the following year. The mine remained idle from 1934 to 1937, at which time it was acquired by Dale Strickler. Strickler operated through the summer and fall of 1937, and through 1938 in a locality about a quarter of a mile south and at a higher level than Schwartz's original discovery. He developed an orebody with two adits in the side of the hill, and treated his ore in a D retort.

The Anderson mine lies in a region of Franciscan rocks which are typical of the Mayacmas district. The belt or zone of mineralization strikes northwest and extends from the outcrop in the creek bed (mentioned in the preceding paragraph) through the Anderson property and on south through the Big Chief property. This belt has not been explored to any great extent north of Anderson Springs. The mineralization occurs in a highly altered, fractured, and folded greenish sandstone carrying cinnabar, associated with pyrites and calcite, as impregnation, and along seams and fracture planes.

Bacon Consolidated mine (Barnum) is in secs. 11 and 12, T. 10 N., R. 8 W., M.D., on the crest of the Mayacmas Range. It is reported to have been a producer in 1876 and 1877, but has not been operated recently.[10]

Big Chief mine is in secs. 25 and 35, T. 11 N., R. 8 W., M.D., in the Mayacmas district, about a quarter of a mile south of Anderson Springs, adjoining the Anderson mine. Howard H. Barrows, 1648 16th Street, Oakland, California, has purchased this mine, also the Anderson and Thorne mines, both of which are mentioned separately in this report, to form a group comprising 172 acres of patented land plus six unpatented mining claims adjoining to the south of the patented land.

This property first produced in 1918, when operated by R. B. Crowell, lessee, although cinnabar in the vicinity had been noticed many years before. Crowell did not operate during 1919, but resumed work on a small scale during the year 1920. No further activity of any note took place on the property until 1928, when the Big Chief Mining Corporation, headed by Clarence Lindville, took an option on the mine. This company did considerable development work in blocking out an orebody with adits in the side of the hill, although most of the ore was taken from open cuts. John Andrews installed a small 2- by 20-foot rotary kiln for the company, but little success was experienced with the furnace. In 1929,

---

[9] Ransome, Alfred L., and Kellogg, John L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, pp. 384-385, 1939.

[10] Yates, R. G., and Hilpert, L. S., Quicksilver deposits of the eastern Mayacmas district, Lake and Napa Counties, California: California Jour. Mines and Geology, vol. 42, p. 279, 1946.

the Big Chief Company gave up its bond, and the property remained idle until 1931. At that time L. R. Messer commenced operations, under lease, and he also encountered difficulties with the furnace.

In 1945, the property was leased to John Johnson, Mission Hotel, 520 South Van Ness Avenue, San Francisco, and Vic Holmstead, and these men were working. The Victoria, a 40-acre tract, the SE¼ NE¼ section 35, is not included in this lease. Johnson first attempted to concentrate some dump ore on the Thorne property with a jig, but he ran out of water. During the summer he was cleaning out the Vic tunnel to reach a point under the glory hole on the Big Chief. Heat in the underground workings is troublesome, as is the case at the Sulphur Bank mine.

H. H. Barrows, states that this combined group of the Anderson, Big Chief, and Thorne is on a belt of mineralization that extends for a width of 200 feet and length of 2 miles. A prominent feature of this belt is an outcrop of white silicified material that resembles chert, and that carries cinnabar in fractures here and there. Some of the Franciscan sandstone contains disseminated cinnabar. Basaltic dikes, which are a prominent feature of the geology, have not yet been mapped in detail. Barrows believes that proper development work may open enough ore so that the property can be put on production of roughly 200 tons per day from open pits.

Big Injun mine is in sec. 35, T. 11 N., R. 8 W., M.D., about a mile southwest of the Big Chief mine, and is owned by Mrs. Alice (Fisher) Armstrong of Calistoga. Cinnabar occurs in brecciated sandstone and shale (Franciscan) at a contact with silica-carbonate rock. Yates and Hilpert [11] report a production of 250 flasks of quicksilver in 1916-17.

Bullion mine (Northwest) is in sec. 23, T. 10 N., R. 7 W., M.D., about 3½ miles south of Middletown. At one time it was worked in conjunction with the Mirabel mine, but apparently has not been operated since 1903.

Chicago mine (St. Louis, Pittsburg, Ural) is in sec. 1, T. 10 N., R. 8 W., M.D., on Dry Creek, 6 miles by road southwest of Middletown, and is owned by F. G. Johnson of Yountville, and G. N. Johnson, G. M. Hobson, and G. H. Hobson. Production of 9 flasks of quicksilver was made in 1942 by W. B. Coffey of El Cerrito, who held a lease. Cinnabar is found in a ledge of silica-carbonate rock. Workings consist of 1,500 feet of drifts, cross cuts, and shafts. Further details of the geology are described by Yates and Hilpert.[12]

Great Western mine [13] in secs. 16, 21, and 22, T. 10 N., R. 7 W., M.D., is on the northern slope of Mount St. Helena, at an elevation of over 2,000 feet. It lies 2 miles northwest of the Mirabel mine and 5 miles southwest of Middletown by paved highway and dirt road. The mine is assessed to the estate of W. F. Detert, and is leased to Bradley Mining Company, 425 Crocker Building, San Francisco, of which Worthen Bradley is president. The Great Western mine was opened in 1873, and

[11] Op. cit., p. 285.
[12] Op. cit., pp. 276-277.
[13] Hanks, Henry G., Annual report of the State Mineralogist from June 1, 1880 to December 1, 1880: California Min. Bur. Rept. 1, p. 26, 1880.
Hanks, Henry G., Catalogue and description of the minerals of California as far as known, with special reference to those having an economic value: California Min. Bur. Rept. 4, pp. 338-341, 1884.

remained a continual producer for more than 35 years. It was operated by the Great Western Quicksilver Mining Company for most of this period, the operations centering in an area which lies to the east and at a slightly lower elevation than the present workings. There were two brick furnaces on the property, one a coarse-ore and the other a Scott furnace. Production began to decrease during 1906, and by 1911 the mine was abandoned as being worked out. In 1912, and again during 1915 and 1916, lessees worked over the old dumps with concentrating devices and managed to produce a small amount of quicksilver, but there was no activity from 1916-31. In 1931, E. J. Bumstead organized the Bumstead Mining Company with himself as manager, purchased the mine, and started operations. Bumstead did not attempt to develop the mine through the old entry. Instead, he centered his operations on the western side of the ridge, at a higher elevation than the old shaft and plant. A 20-ton 5-hearth Herreshoff furnace and a modern condensing system were installed and production was moderate for 4 years. A temporary shutdown lasted through 1935, and in 1936 the property was leased by the Bradley Mining Company. Operations have been continuous from that date to the present time (summer of 1945). The furnace was removed in 1944.

The geology of the Great Western mine has been discussed to some extent by Becker,[14] Bradley,[15] and Schuette.[16]

Mineralization occurs at the contact of serpentine and chert. To the south of the contact is a large Tertiary lava flow. There has been considerable brecciation of both the serpentine and chert in the zone of contact, with silification of the serpentine after brecciation; but apparently no alteration of the chert. The ore formerly mined was found as cinnabar entirely in the chert in numerous seams and on fracture faces.

Ore produced in recent years has come from open pits on the same side of the ridge as the older workings; that is, the opposite side of the ridge from the furnace-plant. A lower pit was mined from 1941-43, and an upper pit in 1944. The upper pit is about 400 feet south of the old shaft, and in the bottom ore in place is associated with a dike of serpentine intruded into a chert and shale series. The serpentine wall of the ore strikes westward and dips 70° S. In August 1935 an adit level was being driven 120 feet below the floor of this pit, and at the 800-foot point was approaching a point vertically beneath the pit. The face of

---

[13] (Cont.)

Hanks, Henry G., California minerals: California Min. Bur. Rept. 6, pt. 1, p. 122, 1886.

Irelan, William Jr., Lake County: California Min. Bur. Rept. 8, p. 325, 1888.

Crawford, J. J., Mines and mining products of California: California Min. Bur. Rept. 12, p. 361, 1894.

Crawford, J. J., Quicksilver: California Min. Bur. Rept. 13, pp. 595-596, 1896.

Bradley, Walter W., Lake County: California Min. Bur. Rept. 14, p. 231, 1916.

Huguenin, E., and Castello, W. O., Lake County: California Min. Bur. Rept. 17, p. 81, 1921.

Averill, Charles Volney, Lake County: California Div. Mines and Mining, Rept. 25, p. 355, 1929.

Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, pp. 388-391, 1939.

Forstner, William, The quicksilver resources of California: California Min. Bur. Bull. 27, p. 62, 1903.

Bradley, Walter W., Quicksilver resources of California, with a section on metallurgy and ore-dressing: California Min. Bur. Bull. 78, p. 58, 1918.

[14] Becker, G. F., Geology of the quicksilver deposits of the Pacific slope: U.S. Geol. Survey Mon. 13, p. 358, 1888.

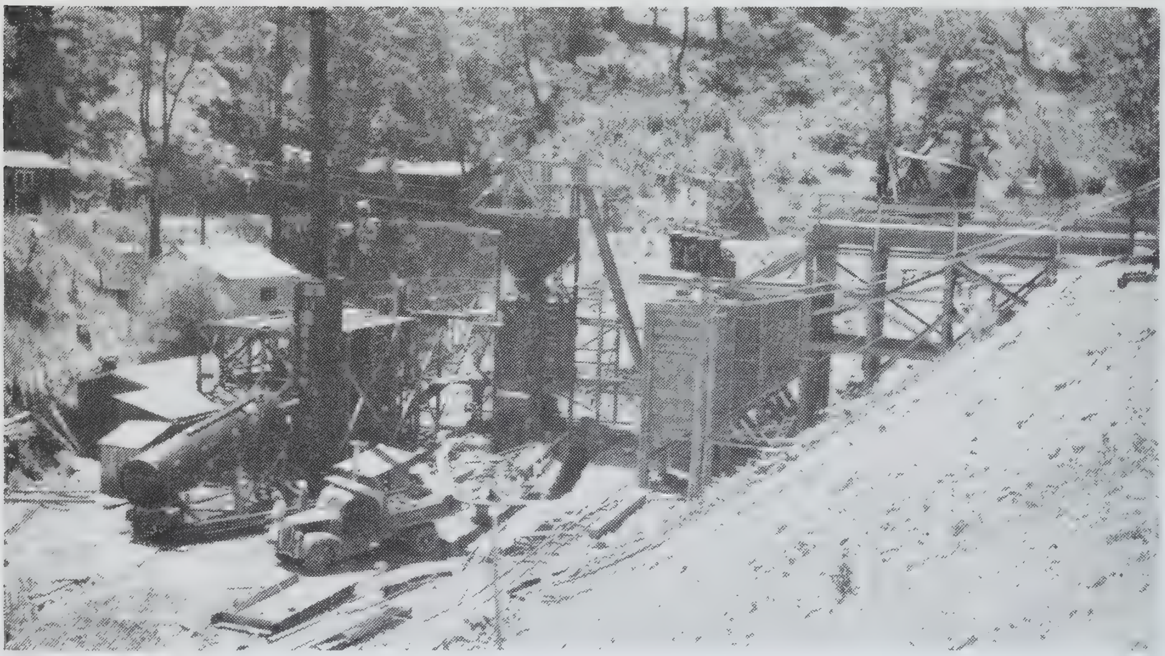
[15] Bradley, W. W., Quicksilver resources of California: California Min. Bur. Bull. 78, p. 58, 1918.

[16] Schuette, C. N., Occurrence of quicksilver orebodies: Am. Inst. Min. and Met. Eng., Trans. 1931, pp. 428-429, 1931.

ABBOTT QUICKSILVER MINE, LAKE COUNTY, CALIFORNIA

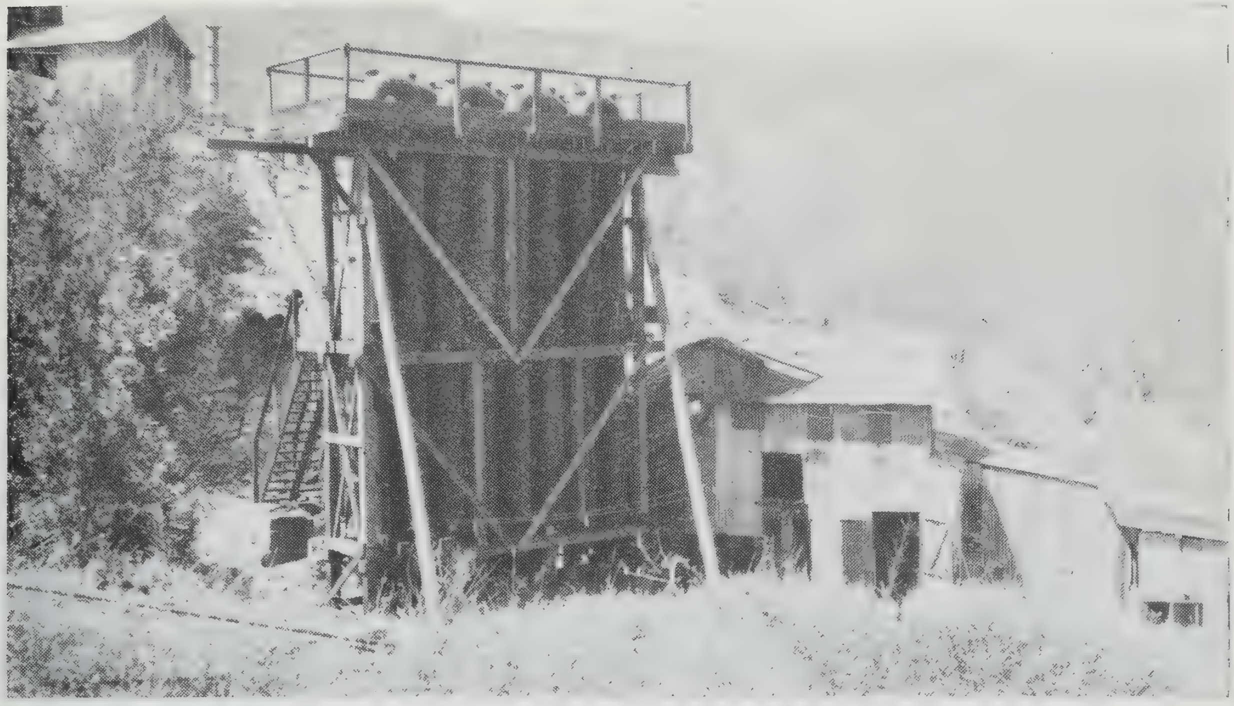
5- -70558

A, UPPER PIT OF GREAT WESTERN MINE,
LAKE COUNTY, CALIFORNIA



B, HERRESHOFF FURNACE

Formerly at Great Western mine; building had burned when photo was taken.
Photos by courtesy of Worthen Bradley.



A, FURNACE PLANT AT HELEN MINE, LAKE COUNTY, CALIFORNIA

Showing condenser of cast-iron pipe.

B, SULPHUR BANK MINE, LAKE COUNTY, CALIFORNIA

Clear Lake in background.

A, SULPHUR BANK MINE, LAKE COUNTY, CALIFORNIA

Open pit.

B. METALLURGICAL PLANT, SULPHUR BANK MINE

Photo by courtesy of Worthen Bradley.

this working was in a sedimentary formation consisting of alternating bands of chert and shale about an inch wide. The formation must be folded and faulted, as considerable variation in strike and dip was noted.

The table which follows gives the production costs (exclusive of taxes and insurance) at the Great Western mine for the month of January 1938.

General costs for mining, milling, etc., at the Great Western mine—January 1938 *

Tonnage treated: 22 tons per day, 30 furnace days; total 664 tons
Grade of ore mined: 12.2 pounds per ton
Grade of ore furnaced: 15.1 pounds per ton
Percent waste sorted out: 18.8
Flasks produced: 132

Item	*Cost per ton handled*	*Cost per ton furnaced*
Development	$1.16	$1.60
Mining	1.32	1.83
Reduction	1.44	1.98
Sorting	.14	.19
Miscellaneous work	.13	.18
Overhead	.32	.45
Selling expense	.07	.10
Total	$4.58	$6.33

*These figures are higher than the monthly average.

Helen mine (American), 570 acres in secs. 1, 11, and 12, T. 10 N., R. 8 W., M.D., was assessed in 1945 to Klau mine, Inc., 1000 Mills Building, San Francisco. It is about 6 miles west of Middletown by steep mountain road, half of which is county road and the remainder private road, and is in the Mayacmas district. To the north is the Chicago mine, and to the northwest is the Wall Street mine, both within a mile.

The first recorded production from this property was made in 1873, and the claims were patented the following year. The mine has been a very consistent, although not a particularly large, producer to the present time, with a total recorded yield to 1939 of over 6,000 flasks. (Total output claimed to be 16,000 flasks.) The property was first worked by one Puchbecker who later sold to the American Mining Company. In 1900, Andrew Rocca, Sr., purchased the mine and began production two years later, after doing some development work. Rocca operated here for more than 20 years, using a 50-ton Scott furnace to treat the ore and a retort for the soot from the condensing system. In 1924, the Pacific Coast Mines Development Company installed a 30- by 40-foot rotary furnace and operated the property for a short time. In 1926, the mine was operated under lease by the Mineral Mountain Mines Company, and a small production was realized. H. W. Gould purchased the property from Rocca in 1927, and leased to L. S. Peterson in 1928. Peterson produced quicksilver on a small scale for several years; then a number of other persons held leases and did some development work, but Peterson was again interested in the lease in 1945. This lease was held by Scott Kline and L. S. Peterson, Middletown. The Helen mine lies on the contact of serpentine and Franciscan sandstone. Movement along the contact zone has brecciated the serpentine to some extent, and has formed a gouge on the hangingwall of the fault. The footwall is serpentine which has been silicified to a great

extent, and contains lenses of black opaline material. Beyond the gouge on the hangingwall is an area of sandstone. A general zone of mineralization has a northwest strike and southwest dip of from 35° to 41°. Old operations were on three orebodies, two of which were in this zone and were called No. 1 and No. 2. No. 3 orebody was vertical and was in the serpentine (altered basalt) opposite No. 2 orebody. The distance between No. 3 and No. 2 on the Santa Maria or 300-level, which is now the main working level, is 220 feet. This distance is greater on the 400-level, an adit which is not in use. The 300-level passes through the northwest edge of the vertical No. 3 orebody; then turns to the northwest. Work in August 1945 was in a 25-foot raise at the 800-foot point of the 300-level. Pockets of ore were being found between No. 2 orebody and the projected position of No. 4 orebody.

No. 4 orebody was discovered by L. S. Peterson in 1933 at a point about 500 feet northwest of the vertical (No. 3) orebody in the serpentine. The hangingwall is sandstone, and the footwall is serpentine. The dip is 35° to 41° southwest. Ore has been mined to a depth of 150 feet for a length of 100 feet. The ore was in pockets, of which the widest was 22 feet. Some parts of the zone were too low in grade to mine. Peterson states that ore goes on down at 150-foot depth, but that the stopes have caved. Another lessee drove a raise 150 of the total of 225 feet estimated to be needed to reach this ore at 150-foot depth on No. 4 orebody.

Details of the geology of this mine including a map and sections have been published by Yates and Hilpert.[17]

The mine is equipped with a complete Gould furnace plant including rotary furnace with shell 36 inches in diameter by 36 feet long, suction-fan, cyclone dust collector, and condenser. The condenser consists of 28 lengths of 16-inch cast-iron pipe, each 12 feet long, arranged in vertical stands each two lengths high, with return bends at the top and hoppers at the bottom with openings for draining condensed quicksilver into buckets of water. Power is furnished by a 25-horsepower Fairbanks-Morse Z engine burning stove oil and driving a 250-volt generator. Capacity of the plant is about 25 tons of ore per 24 hours.

Jewess mine is in sec. 1, T. 10 N., R. 8 W., M.D., 4 miles southwest of Middletown, about 1 mile east of the Helen mine. It is reputed to have produced 60 to 100 flasks of quicksilver but has not been operated recently.

Joyce prospect is in sec. 14, T. 10 N., R. 7 W., M.D., about three quarters of a mile northwest of the Mirabel mine on State Highway 29. It has been developed by means of two small shafts, and a small amount of quicksilver has been produced.

Konocti mine (Bell) is in sec. 21, T. 13 N., R. 8 W., M.D., 5 miles in an air-line southeast of Kelseyville. Hundreds of feet of bulldozer cuts have been made recently in the white kaolinized country rock in a search for cinnabar, but the mine was idle in July 1945. An old mill indicates that some quicksilver may have been produced long ago.

Two hundred and fifty tons of the white kaolinized rock that was free of grit has been shipped from this property as china-clay by Ed. Auschwitz, Rural Route, Kelseyville, but the particular lens from which shipments were made has been exhausted.

[17] Op. cit., pp. 277-279.

Midway mine is in sec. 17, T. 10 N., R. 7 W., M.D., on the south fork of Dry Creek, about 4 miles by road from Middletown. It is owned by Elbert J. Wilkinson of Middletown. Some quicksilver has been produced from short tunnels and open cuts. Ore was concentrated on a table, and the concentrate was retorted. Cinnabar impregnates sandstone along a fault zone. Additional development work is needed.

Mirabel mine[18] (Bradford, Bullion) in sec. 14, 22 (Bullion), and 23, T. 10 N., R. 7 W., M.D., 4 miles by paved road south of Middletown, is operated by Mirabel Quicksilver Mining Company, Middletown. W. E. Best, who lives at the mine, is president, and Renaldo Urbani is foreman. State Highway 29 passes through the property.

With the exception of minor corrections and notes on present (1945) operations, the following description is reprinted from the report of Ransome and Kellogg previously cited.[19]

The Mirabel mine has an interesting history which is revealed in a private report by J. McL. Harvey, former agent for the Standard Quicksilver Company. Mr. W. E. Best, president of the present operating company, was kind enough to allow the authors to read this report from which are presented the following facts:

In the early seventies a cinnabar deposit was noted in the vicinity of the existing property and subsequently named the Great Eastern mine. On this claim the major workings are located today. A shaft was sunk near the creek bed, but it was soon flooded and the mine was abandoned. In 1887, an early Lake County settler named Bradford ran across cinnabar float on his property, in the bottom of St. Helena Creek, a short distance below the Great Eastern mine. Some time later, while reputedly sinking a well, he hit a large body of cinnabar. Bradford and his sons operated the newly discovered mine for about 6 years. In 1893, three men (Mills, Randol, and Bell) formed the Standard Quicksilver Company. They purchased the mine for a reported price of $500,000, renamed it the Mirabel mine and commenced operations on a large scale. Two furnaces were constructed, one a coarse-ore furnace of 15 tons capacity and the other a Scott fine-ore furnace of 48 tons capacity. The latter has recently been wrecked. The Standard Company owned about 750 acres of land patented by Bradford, including the Plymouth claim, the Great Eastern claim, the Mirabel proper, and the Bullion claim. Operations continued for a period of 5 years; but by 1897, the ore reserves were gone and the Mirabel was abandoned as worked out. Operations continued on a small scale at the Bullion property, but it was abandoned in

[18] Fairbanks, Harold W., Notes on the geology and mineralogy of portions of Tehama, Colusa, Lake, and Napa Counties: California Min. Bur. Rept. 11, p. 64, 1893.
Crawford, J. J., Mines and mining products of California: California Min. Bur. Rept. 12, p. 361, 1894.
Crawford, J. J., Quicksilver: California Min. Bur. Rept. 13, p. 596, 1896.
Bradley, Walter W., Lake County: California Min. Bur. Rept. 14, p. 233, 1916.
Averill, Charles Volney, Lake County: California Div. Mines and Mining, Rept. 25, p. 357, 1929.
Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, pp. 392-395, 1939.
Yates, R. G., and Hilpert, L. S., Quicksilver deposits of the eastern Mayacmas district, Lake and Napa Counties, California: California Jour. Mines and Geology, vol. 42, pp. 273-275, 1946.
Forstner, William, The quicksilver resources of California: California Min. Bur. Bull. 27, p. 60, 1903.
Bradley, Walter W., Quicksilver resources of California: California Min. Bur. Bull. 78, p. 62, 1918.
Becker, William, Mirabel quicksilver: Min. World, vol. 1, no. 3, p. 9, 1939.

[19] Ransome, A. L., and Kellog, J. L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, pp. 392-395, 1939.

1903. A period of idleness ensued which lasted nearly 25 years, and was broken only by a few lessees in 1908, 1914, and 1916, who cleaned up a few flasks around the dumps and furnaces. In 1928, H. C. and L. H. Davey and John W. Doman took a lease on the property with an option to buy, and entered on an extensive development program. Only the ore which was the result of development was treated. The Mirabel Quicksilver Mining Company was then formed, with H. C. Davey as superintendent, and the property was purchased in 1929. Actual operations, under this company, began in 1930 and have been continuous to the present time. Early in 1934, W. E. Best was named president of the company, and he took charge at the mine that year.

The ore at the Mirabel mine is found in lenses of silicified serpentine; the occurrence of the cinnabar is similar in many respects to the deposits of the more recent workings of the Great Western mine. The main points of similarity are: (1) the general silicified character of the ledge material; (2) the occurrence of hydrocarbons associated with mineral deposition (the presence of these hydrocarbons is considered a good guide to ore in both deposits); and (3) the fact that ore deposition has occurred in both cases, either on the contact of, or in, the serpentine as distinct mineralized zones. In the zones at the Mirabel mine, the cinnabar is found primarily as fissure filling in a series of small, irregular veins and as a breccia filling. Frequently native quicksilver, and occasionally metacinnabar, are found associated with the cinnabar. Dolomite, often well crystallized, is prominent as a gangue mineral.

The deposits of the Great Western mine lie near or on the contact of serpentine and chert; whereas the deposits of the Mirabel mine are located at the contact of serpentine with Franciscan sandstones and shales.

The mine was formerly worked in two separate areas. One of these was the old Great Eastern ore body developed by a single-compartment 350-foot vertical shaft just east of St. Helena Creek, and an inclined winze on the 465-foot level. In 1945 no work was being done from this shaft, but it was kept unwatered to the 275-foot level.

About a quarter of a mile farther north and on the west side of the creek, just west of the highway, is the Bradford shaft, a 350-foot vertical shaft, from which development work was proceeding in the summer of 1945. On the north side of this shaft, the 180-foot level is an intermediate, which does not connect with the shaft. At a point 400 feet north of the shaft, a raise was being driven along the north side of an old stope in search of an orebody thought to be present. An additional 60 feet would connect this with the 120-foot level. On the south side of the shaft the 180-foot level connects with the shaft, and at a point 400 feet south of the shaft, a second raise was being driven to explore some new ground that had been diamond-drilled. Considerable stoping has been done from the Bradford shaft, first by the shrinkage method, but later by square-setting. Considerable drifting and diamond-drilling have been done on the Plymouth claim, but the ore was low in grade. In the summer of 1945, the total crew was 10 men.

The metallurgical plant near the Great Eastern shaft was not in operation in the summer of 1945. When ore is being treated, it is first crushed in jaw crusher set below the primary bin to about $\frac{3}{4}$-inch size; then goes to the fine-ore bin. It is then fed to a rotary furnace by means

of a 6-inch Selway rotary feeder, which consists of a revolving pipe from a small hopper extending into the furnace at the upper end. The rotary furnace is 30 feet long by 30 inches inside diameter and has a rated capacity of 25 tons per 24 hours. It is set on a slope of one inch per linear foot, and revolves at a speed of about 2-2½ r.p.m. An 18-gravity fuel oil is used to fire the furnace, which has an average consumption of 11 to 12 gallons per ton of ore treated. Furnace gases pass through an 8-inch Sirocco dust collector into the condensing unit which is made up of ten 16-inch diameter steel pipes a quarter of an inch thick and 18 feet long. From 2 baffled redwood settling tanks the gases pass through about 200 feet of 16-inch tile pipe to the stack, which is situated some 75 feet away, up the hill. Soot and mercury from the condensing system are hoed with unslaked lime on a table set up under a ventilating hood, and the remaining soot is returned to the feed end of the furnace. Calcined ore is dropped into a small concrete bin, below the firing end of the furnace, and is hauled up an inclined ramp in cars by means of a small air tugger. The ore is dumped near the creek, where high water washes most of it away.

The entire system of furnace and condensing units is kept under close control as to temperature and draft, at the critical points, by a series of recording pyrometers and U-tube manometers.

Otto-Bullion mine is in sec. 22, T. 10 N., R. 7 W., M.D., 5 miles south of Middletown. In 1944, development work was being done by Bradley Mining Company of San Francisco. Two levels of a total length of 270 feet had been driven from a 163-foot shaft.

Plymouth mine [20] in sec. 24, T. 10 N., R. 7 W., M.D., is part of the property of Mirabel Mining Company. Development consists of 2,500 feet of workings, but parts of these workings are inaccessible because the mine has not been operated recently. It is about a quarter of a mile southeast of the Great Eastern shaft. Recent (1945) development work consisting of drifting and diamond drilling developed ore of low grade only.

Red Elephant mine [21] is in sec. 3, T. 11 N., R. 5 W., M.D. Cinnabar ore has been found along a shear zone about 2 miles long. This zone has a strike which is west of north and a dip of about 45° northeast. The mine was reopened in the fall of 1941, and a new 20-ton rotary furnace was installed. Development work was done in 1942 along the shear zone south of the older workings from a new inclined shaft. However, the mine was abandoned during the winter of 1942-43, and subsequently all of the equipment was removed, and the mine was allowed to fill with water.

Research mine is in sec. 1, T. 10 N., R. 8 W., M.D., on the south side of Dry Creek, 6 miles by road from Middletown. In July 1943, it was claimed by Otto Koopman of San Francisco and Fred Herman of Middletown. In 1941, it was leased by W. B. Coffey of El Cerrito, who did some development work. A few details of the geology are given by Yates and Hilpert.[22]

---

[20] Yates and Hilpert, op. cit., p. 275.

[21] Averitt, Paul, Quicksilver deposits of the Knoxville district, Napa, Yolo, and Lake Counties, California: California Jour. Mines and Geology, vol. 41, pp. 65-89, 1945.

[22] Op. cit., p. 281.

Rich Hill mine (Hardester, Bucksnorter) is in SE¼ sec. 19, T. 10 N., R. 6 W., M.D., and is owned by Scott Kline of Middletown. Cinnabar is disseminated through sandstone in the vicinity of a fault zone. Production during the years 1934-37 amounted to about 25 flasks.

Sulphur Bank mine [23] of about 800 acres is mainly in sec. 6, T. 13 N., R. 7 W., M.D., on the southeast shore of Clear Lake in the Clear Lake district. The town of Lower Lake is about 10 miles to the south, and State Highway 20 passes the mine about 2 miles to the north. Dirt roads connect the mine with the state highway and with the Lower Lake road at Clear Lake Park. The mine is owned by Bradley Mining Company, 425 Crocker Building, San Francisco, of which Worthen Bradley is president. A. F. Wolbert, Clear Lake Park, is superintendent at the mine.

The following description is reproduced from an earlier Division of Mines report [24] with minor changes to bring it up to date.

The early history of the mine dates back to 1865, when the deposit was exploited for the free sulphur present by the California Borax Company. This company found that at a depth below the sulphur-bearing horizon, the amount of cinnabar present made refining of the sulphur extremely difficult and expensive. In 1868, a rapid fall in the price of sulphur caused the company to cease operations. Interest in quicksilver began to increase with the boom prices of the seventies, and the California Borax Company decided to capitalize on their previously troublesome by-product. Production of quicksilver started in 1873, and continued steadily for a 10-year period, at the end of which period a decreasing price for the metal caused a second shut-down. Four years later the mine was reopened by the Sulphur Bank Quicksilver Mining Company, and they operated for a 10-year period. The Empire Consolidated Mining Company took over the mine in 1899, and produced a little metal until 1902.

During these early years of production, the ore was mined from open cuts and from underground workings. Because of the presence of sulphur dioxide fumes and high underground heat, it is difficult to con-

---

[23] Hanks, Henry G., Annual report of the State Mineralogist from June 1, 1880 to December 1, 1880: California Min. Bur. Rept. 1, p. 26, 1880.

Hanks, Henry G., Catalogue and description of the minerals of California as far as known, with special reference to those having an economic value: California Min. Bur. Rept. 4, pp. 339, 341, 1884.

Hanks, Henry G., Fifth annual report of the State Mineralogist: California Min. Bur. Rept. 5, p. 96, 1885.

Hanks, Henry G., California minerals: California Min. Bur. Rept. 6, pt. 1, p. 122, 1886.

Irelan, William Jr., Lake County: California Min. Bur. Rept. 8, pp. 324-325, 1888.

Crawford, J. J., Mines and mining products of California: California Min. Bur. Rept. 12, pp. 361-362, 1894.

Crawford, J. J., Quicksilver: California Min. Bur. Rept. 13, p. 597, 1896.

Bradley, Walter W., Lake County: California Min. Bur. Rept. 14, pp. 234-238, 1916.

Huguenin, E., and Castello, W. O., Lake County: California Min. Bur. Rept. 17, p. 82, 1921.

Averill, Charles Volney, Lake County: California Div. Mines and Mining, Rept. 25, pp. 358-363, 1929.

Everhart, Donald L., Quicksilver deposits at the Sulphur Bank mine, Lake County, California: California Jour. Mines and Geology, vol. 42, pp. 125-153, 8 figs., pls. 21-22, 1946. (Detailed maps of the Sulphur Bank mine and three mimeographed pages of description of the geology, prepared in 1943 by D. L. Everhart of the U.S. Geological Survey, are on file in the San Francisco office of the Division of Mines.)

Forstner, William, The quicksilver resources of California: California Min. Bur. Bull. 27, p. 61, 1903.

Bradley, Walter W., Quicksilver resources of California: California Min. Bur. Bull. 78, p. 63, 1918.

Bradley, Worthen, and Hall, R. G., Concurrent firing at the Sulphur Bank and Reed quicksilver plants: Am. Inst. Min. Met. Eng., Tech. Paper 1889, Metals Technology, December 1945.

[24] Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, pp. 395-400, 1939.

ceive how miners were able to accomplish anything while working underground. It is said that the men worked in 20-minute shifts, and were constantly sprayed with water while in the mine. Ore was reduced in a 25-ton Knox-Osborne furnace, three Scott furnaces of 40, 30, and 17 tons capacity, and a battery of D retorts.

There was no activity on the property from 1902 until 1915. At this time the Sulphur Bank Association, of San Francisco, acquired the property under lease and bond, and began doing some surface work which lasted through the war period. The ore mined was treated in retorts during this period. A rotary furnace was installed in 1918, but was operated only a short time. Following the war the mine was idle until 1927. Since 1927 production has been continuous.

Sulphur Bank is a low, rounded hill on the shore of Clear Lake, and is situated in an area of Franciscan rocks overlain by a series of fresh-water sediments of Pliocene-Pleistocene age capped by a Pleistocene basalt flow. The sediments (frequently referred to as Cache Lake beds) consist of flat-lying sands and conglomerates deposited on a series of horizontal Franciscan shales and sandstones. A basalt extrusion broke through the overlying sedimentary strata, possibly at a point near the shore of Clear Lake, and spread out in a sheet over the sediments. Upon cooling, this basalt developed shrinkage cracks, and formed the well-known pillow structure commonly found in extrusive rocks which have been cooled under water. Solfataric action has altered the rock to a great extent, with concentric weathering of the basalt common throughout the deposit.

A thrust fault strikes approximately eastward across the southern extent of the mine workings. Through rifts in the hanging, or north wall, hot sulphurous waters and steam now escape. The mineralizing solutions that probably rose through these rifts, were to a certain degree trapped by the overlying basalt, and deposited cinnabar at this point. The basalt sheet is not very extensive, being bound on the north and west by the waters of Clear Lake. To the south it may have been faulted off and the faulted section eroded away, or it may have stopped in its flow before reaching the fault zone.

Cinnabar occurs closely associated with the basalt and, at depth, it is said to have been deposited in the fractured sedimentary rocks. The principal occurrence is in an altered material which has filled the shrinkage cracks between the basalt pillows. Frequently it is found as fracture fillings of the rock, and several cases were noted where the cinnabar has actually impregnated the basalt.

Ore is found in commercial quantities from a depth of 30 or 40 feet below the surface level to the lowest workings, which are more than 150 feet deep. The upper horizon contained sulphur in commercial quantities, and it was mined during the first years of operations. Sulphur is still a plentiful and closely associated mineral. Boiling hot springs are numerous throughout the area, and in one case action is of sufficient violence to throw a continual spray of mud and water into the air. It is quite certain that mineralization is proceeding at the present time in many of the springs and steam vents.

Mining at the Sulphur Bank is done entirely in open pits. A. F. Wolbert, superintendent at the mine, stated that a short drift was run not long ago, and before it had reached 50 feet in length the heat was so

intense that, regardless of the fact that air under forced draft was delivered constantly to the face, the men were unable to work for more than half-hour periods. This situation soon caused the management to give up the project. Evidence of former mining activities on the property is noticeable over an area of about 100 acres. Old shafts, pits, and trenches are too numerous to be mentioned separately. Mining activities in 1945 were centered in an open pit more than 100 feet deep, the bottom of which is roughly 60 to 70 feet below the surface of the water in Clear Lake. Power-shovels are used in the pit, and both ore and waste are hauled out with trucks. Trucks are of 10-cubic-yard and 6-cubic-yard capacity. The 6-cubic-yard ''Dumptor'' truck has three speeds forward and three speeds in reverse, and is often driven from the pit in reverse. In 1943, material removed from the pit amounted to 1,250,000 tons. Prospecting is done with churn-drills, and these sometimes strike flows of hot water which is under pressure. Hydrogen sulphide sometimes collects in the pit, and must be blown out from low places with compressed air before men can work.

Ore from the mine is dumped through a grizzly into a primary ore bin. A 10- by 20-inch Blake jaw crusher breaks the oversize rock to about 2-inch size. It is then transported by a series of conveyor belts to a hopper at the upper end of a 5- by 60-foot rotary furnace. As the ore drops from the conveyor belt to the hopper, the stream is cut at 5-minute intervals by an automatic device which diverts the flow into a sample box. Feed to the kiln is by gravity.

The firing of the furnace at Sulphur Bank is unique in modern metallurgical practices. Because of the high sulphur content in the ore treated, it was found that in order to get complete combustion of sulphur, the firing must be done at the feed end of the furnace. With good temperature control no unburned sulphur vapors now enter the stream; and, consequently, there is no recombination of mercury and sulphur in the condensing system. Fuel oil used for firing is a 19 gravity oil, and the consumption for the year 1937 averaged 12.95 gallons per wet ton of ore treated. The rotary furnace, when first built, had a diameter of 5 feet and was only 40 feet long. Later a 20-foot section was added, with a view to increasing the tonnage. The capacity, however, was not increased despite the fact that the furnace became more efficient at burning out the sulphur. It is set at a slope of half an inch to the linear foot, and rotates about $1\frac{1}{2}$ to 2 r.p.m. The method of disposal of calcined ore is quite interesting. From the lower end of the furnace it is carried by a rotating pipe to a steel tank, from which it is drawn off from time to time into dump trucks, and spread upon the roads.

Gases leave the furnace and enter a Sirocco dust collector at a temperature of 1155° F. (625° C.) and because of this exceptional heat, a very large and complicated condensing system is required. The primary condensing system formerly consisted of three parallel rows of mild steel vertical pipes 10 inches in diameter and 26 feet high, with six pipes per row. This was followed by five parallel rows of steel vertical pipes 10 inches in diameter and 9 feet high, with five pipes per row; and five parallel rows of vertical tile pipes, 10 inches in diameter and 9 feet high with 12 pipes per row. This is a total of 103 pipes. Extensive experiments were made with stainless steel to determine the best composition for resisting the corrosive gases. As a result the cooler end of the condensing

system amounting to about half of it, and including the tile pipe, was replaced with stainless steel pipe containing the following: carbon 0.08%, manganese 1.80%, phosphorous 0.02%, sulphur 0.01%, silica 0.24%, nickel 12.80%, chromium 18.44%, molybdenum 2.35%. The temperature where the change is made from mild steel to stainless steel is about 400° F. Mild steel is satisfactory for the hot end because the hot gases are not so corrosive. Gases pass from the primary condensing system to a secondary system consisting of two concrete tanks, 10 feet in diameter and 24 feet high, into which water is sprayed. A fan operates between these two tanks, and gases leave the second tank through a 30-inch wooden stack.

The low-grade mud from the secondary unit is sent to two thickeners. The partially dewatered product is pumped to an agitator, whence it is sent to a two-cell flotation unit.[25] The concentrates are filtered, dried, and retorted in one double, oil-fired D retort. Soot and mercury which are collected from the primary system are mechanically agitated with unslaked lime, and the remaining mud joins the flotation concentrates in the retorts.

A large flotation plant was installed in 1928, on a hill to the rear of the present mill. If successful, the plant was to treat about 500 tons per day. So many difficulties were encountered, however, that the plant proved to be but a limited success. It is probable that the chief trouble lay in the ever-changing type of ore which was encountered. The plant could not be adjusted rapidly enough to handle these day-to-day changes. Moreover, there was a problem on the subject of the treatment of the concentrates. The cinnabar was so finely divided through the concentrate that it was extremely difficult to make a good extraction in the rotary; at the same time, the grade of the concentrate was not high enough to warrant treatment by retorts. The plant is now partly dismantled.

The following table gives the mining, reduction, and general costs for the year 1937 (exclusive of taxes and insurance).

General costs for mining, milling, etc., at the Sulphur Bank mine
1937

Flasks produced: 2,519
Tonnage treated: 25,398.40 wet tons

Item	Cost per ton	Total cost
Operating expense		
Surface mining	$1.588	$40,325.20
Plant operation	1.705	43,326.35
Power	.339	8,624.41
General expense (S. F. overhead)	.238	6,033.63
Marketing	.338	8,580.45
Camp upkeep	.100	2,547.24
Capital expense	.408	10,376.94
TOTAL	$4.716	$119,814.22

Thorne mine (Bear Canyon) is in sec. 36, T. 11 N., R. 8 W., M. D., 6 miles by road west of Middletown and is part of a group which includes the Big Chief and Anderson mines owned by H. H. Barrows, 1648 16th Street, Oakland. Further details are contained herein under the heading Big Chief.

[25] Bradley, Worthen, Method and cost of recovering quicksilver from low grade ore at the reduction plant of the Sulphur Bank Syndicate: U.S. Bur. Mines Inf. Circ. 6429, pp. 7-8, 1931.

Wall Street mine (Nevada, Cincinnati) is in sec. 1, T. 10 N., R. 8 W., M. D., 5 miles by road from Middletown, and three-quarters of a mile east of the Chicago mine. It is owned by Guy W. Hansen of Concord. The mine is a former producer but has not been operated recently.

Soda

Borax Lake is a closed basin approximately 320 acres in area, situated in secs. 7, 8, 17, and 18, T. 13 N., R. 7 W., M.D. The lake is upon a peninsula projecting into the southeast end of Clear Lake. Borax Lake is of the playa type, and in years of subnormal precipitation may become dry, or nearly dry, near the end of the summer. When this occurs, a heavy incrustation of precipitated salts covers the bed of the lake, surrounding a few acres of shallow concentrated brine in the center of the basin. In the winter months the lake may be covered by a carbonate brine to an average depth of 3 to 5 feet over an area of 200 to 300 acres. Drainage of winter rains into the closed basin apparently dissolves all of the salts precipitated each summer; when the lake is well filled no evidence is seen of crystalline salt deposits on the bottom.

The lake has some possibilities as a source of a limited tonnage of crude trona, because analyses of the water when the lake is well filled indicate 20,000 tons or more of sodium carbonate in solution, some of which is precipitated as a saline crust or as trona reefs near the end of the dry season each year. The following typical analyses (calculated to compounds and reported in grams per liter) show the type and concentration of the brine in Borax Lake.

Compound	*No. 1 (Aug. 1921)**	*No. 2 (Jan. 1947)*
Sodium carbonate	8.360	18.535
Sodium borate	2.515	0.484
Sodium chloride	18.280	1.760
Potassium chloride	1.068	1.780
Sodium sulfate (anh.)	0.074	0.010
Magnesium acid carbonate	0.230	0.099
Miscellaneous and organic	1.053	0.541
Total salinity	31.58 gm/liter	23.209 gm/liter

* Wells, R. C., Note on the water of Borax Lake: Washington Acad. Sci., Jour., vol. 11, no. 20, Dec. 4, 1921, pp. 477-481.

Analysis no. 1 is on a sample taken in August, but the lake was well filled with water because of abundant rain during the preceding winter and spring. The analysis would indicate that some precipitation of trona had taken place, however. Analysis no. 2 is on a sample taken in January 1947. At the time this sample was taken, the lake covered about 300 acres to a depth of 3 to 4 feet, and it was estimated that the following tonnages of salts were present in solution: sodium carbonate, 23,000; sodium borate, 600; potassium chloride, 2,000; common salt, 2000.

In 1936 Borax Lake was almost entirely dry at the end of the summer. Most of the lake bed was a mud flat covered with a heavy crust of crude trona of white to light-brown color. The center of the lake contained about an acre of reddish brine 2 or 3 inches deep, resting on trona beds.

Stone for Building

Many types of stone of volcanic origin that have been used for buildings are available in Lake County. The following are offered as examples; but such stone is, of course, to be found in many other places.

A white rock on Bottlerock road in sec. 7, T. 12 N., R. 8 W., M. D., about 7 miles from Kelseyville, appears to be a rhyolite or possibly a highly indurated tuff. It may be suitable for building but is considerably cut up by joints into irregular blocks. According to Henry Mauldin, county supervisor, it is very durable as road material when used to fill mud-holes. About a quarter of a mile up the road and the same distance to the southwest, in sec. 18, T. 12 N., R. 8 W., M. D., is a gray rock, probably andesite, reached by a quarter-mile of old road in poor condition. This breaks on joints into slabs 2 to 3 inches thick and has been used for stepping-stones. At a sharp bend in the Bottlerock road, 5 miles from Kelseyville or 2 miles from the point where this road leaves State Highway 29, an old road leads to the foundation of an old hotel that was built of local stone at a distance of only a few hundred yards from the Bottlerock road. The stone is almost like obsidian but is cryptocrystalline. Most of the stone in the immediate vicinity, sec. 1, T. 12 N., R. 9 W., M.D., is obsidian.

Near Clear Lake Park, sec. 16, T. 13 N., R. 7 W., M. D., is a colored vesicular lava that has been used for the foundations of buildings at Clear Lake Highlands. The color is various shades of red and brown caused by hematite. A few truck-loads of this stone have been shipped to the San Francisco Bay area. No quarry has been opened; the stone used thus far has been loose chunks from the surface. The deposit is on the ranch known as the Mott place assessed to Charles N. Reid and others, Clear Lake Park. Similar rock is found on the shore of Clear Lake on land owned by W. Henderson of Kelseyville, in sec. 5, T. 13 N., R. 8 W. This occurrence is accessible only by boat; small amounts of the rock have been used.

A nearly white fine-grained tuff has been quarried a quarter of a mile due north of the main buildings at Seigler Springs and has been used in building construction at the springs in sec. 24, T. 12 N., R. 8 W., M. D. A similar deposit in sec. 30, T. 12 N., R. 7 W., about 2 miles to the southeast of the one first mentioned, is a quarter of a mile south of Bonanza Springs on property owned by Edward Stahl, 1600 Market Street, San Francisco. The stone is somewhat coarser in grain here, and the different strata exhibit various shades of white, gray and buff. The stone stands as a bluff 75 feet high and 100 feet long. A few of the fragments in the tuff are half an inch in diameter, but the general grain is much finer. To the east of this bluff at a distance of 500 feet, the tuff outcrops along an old road, but it is not consolidated here and is more of the nature of sand. These tuffs are soft and easily worked when freshly quarried but harden after exposure. Similar tuff has been quarried in sec. 23, T. 13 N., R. 9 W. near Kelseyville; also at another quarry near Middletown.

According to Henry Mauldin, chairman of the Board of Supervisors, Lakeport, abundant stone suitable for stepping-stones is found in sec. 20, T. 12 N., R. 8 W., M. D., near Boggs Lake. In SE¼ sec. 8, T. 12 N., R. 8 W., M. D., is a light-colored rock resembling petrified wood that has been used as ornamental stone in columns, walls, and rock-gardens. Cobble-

stones for walls and other construction have been obtained from Kelsey Creek 1½ to 6 miles south of Kelseyville and from Adobe and Highland Creeks, 3 to 5 miles southwest of Kelseyville. At a point 2 miles due west of Highland Springs, in sec. 35, T. 13 N., R. 10 W., M. D., on property owned by Dr. Neal C. Woods of Lakeport, is a hill of a dark gray rock that has been used in the construction of several buildings at Finley and on farms in the vicinity.

Stone, Miscellaneous

Frazell and Lampson of Lakeport operate a small plant for the production of washed and screened sand and gravel in sec. 14, T. 13 N., R. 9 E., M. D., at the edge of the town of Kelseyville. The gravel on Kelsey Creek has been worked by means of a small stationary dragline to a depth of 50 feet, but the bottom has not yet been exposed. The deposit extends 1½ miles north with widths of an eighth to a quarter of a mile. It has been worked in section 11 to the north by both the state and county to provide gravel for surfacing roads.

Lake County owns a deposit of sand that is used for surfacing roads in sec. 21, T. 13 N., R. 7 W., M. D., just east of Clear Lake Park. The sand grains are obsidian. An open pit about half an acre in area has been excavated to a depth of a few feet, or to a maximum depth in one spot of 10 feet. Some evidence exists that this deposit represents a flow of volcanic glass into a body of water. John Pearce of Clear Lake Highlands owns a similar deposit. Material from road cuts in a sandy volcanic tuff an eighth of a mile northwest of Adams Springs has been used on county roads in that vicinity.

Other Deposits. Other places that have furnished sand and gravel for road material, which has been used by the county, include a deposit at the forks of Scott Creek and Middle Creek near Upper Lake. At this point a trommel has been installed with a capacity of 50 cubic yards in 8 hours of washed gravel ranging from half an inch to an eighth of an inch in size. At a point 4 miles up Middle Creek at Upper Lake is a deposit which is utilized for both sand and gravel.

Sulphur

Auschwitz property owned by Ed. Auschwitz, Rural Route, Kelseyville, is in SW¼ sec. 33, T. 13 N., R. 8 W., M. D., at a point a quarter of a mile southwest of the road from Kelseyville to Lower Lake. Yellow sulphur occurs in white decomposed volcanic rock. An old road goes up a shallow gulch, leaving the main road half a mile northwest of the buildings at the S-Bar-S ranch. Dumps indicate a 50-foot shaft and an adit level with at least two branches of a total length of 100 feet. The shaft is about 25 feet from the portal of the adit. Sulphur on the dumps has been set afire by brush fires, so the original grade of the material is uncertain. The appearance of the road and workings indicates that no work has been done for years. According to A. H. Hoyt of Kelseyville, cinnabar in small amounts has been found on the next property to the southwest.

Sulphur Bank mine, which is described herein under the heading of quicksilver, was a producer of sulphur during the years 1865-68. The amount is given in the table of mineral production.

MINES AND MINERAL RESOURCES OF SAN BENITO COUNTY, CALIFORNIA

By Charles V. Averill *

OUTLINE OF REPORT

ILLUSTRATIONS

GENERAL DESCRIPTION OF THE COUNTY

Introduction

San Benito County was created in 1874 from that part of Monterey County lying northeast of the Gabilan Mountains. An adjustment of the eastern boundary with Fresno and Merced Counties in 1887 increased the area of San Benito County to practically the present size and outline. Mission San Juan Bautista was founded in 1794, thrived until 1835, and was restored in 1888. Its walls still show original decorations painted by the Indians, and its long, arched corridors are still covered by the original tiles. The Mission faces a Plaza Square, which is maintained as a State Park. Other old buildings facing the square from two additional sides form part of the park also. They have been restored and are open to the public.

Geography

San Benito County lies about 100 miles south of San Francisco, extending southeastward from the Pajaro River for 70 miles. The average width is 20 miles. Except for Chittenden Pass, the Coast Range on the western boundary is unbroken, and through this pass sea breezes from

* Mining engineer, California State Division of Mines, Ferry Building, San Francisco. Manuscript submitted for publication January 1947.

Monterey Bay modify a climate which otherwise would be similar to that of the interior valleys. Temperatures in January range from about 36° to 58° F. and in July from 50° to 80° F. Average rainfall is 13.1 inches, 50 percent of which falls from December through February; summers are rainless.

According to the 1940 census, San Benito County had a population of 11,392, practically the same as in 1930. Like all other parts of California, the county has probably increased in population since 1940. The land area is 1,396 square miles.

Transportation is furnished by a branch line of the coast line of the Southern Pacific railroad operated between Gilroy in Santa Clara County and Hollister; also by State Highways 25, 152, and 180. Route 25 runs near the center of the county in a general north-south direction. Route 180 connects a point near the center of the county with Mendota, Fresno County, and Route 152 runs from points in the northern part of San Benito County eastward across the San Joaquin Valley to connect with Highway 99 near a point on the county line between Merced and Madera Counties. County roads, some with all-weather surface, reach various parts of the county.

Topography

San Benito County is an area of valleys, hills, and mountains, almost bisected by the San Benito River, which flows northwestward near the center of the county. Elevations range from less than 100 feet at the Pajaro River in the north to 5,165 feet at the summit of San Benito Peak. Many places in the mountains in the western part have elevations of 3,000 feet or more. Topographic maps on a scale of 1:62,500 or about 1 inch to 1 mile are available for practically all of San Benito County. The following quadrangles of the U. S. Geological Survey show parts of the county: Priest Valley, San Ardo, Hernandez Valley, Metz, San Benito, Gonzales, San Juan Bautista, Hollister, Quien Sabe, Ortigalita Peak, Panoche Valley, and New Idria. An area of a few square miles in the northeastern part of the county that is not covered by these quadrangles on the scale of 1:62,500 is available on the Panoche quadrangle on a scale of 1:125,000.

Geology

Detailed geology of the central part of San Benito County has been mapped by Wilson [1] in the San Benito quadrangle, a 15-minute sheet on a scale of 1:62,500 or approximately 1 inch to 1 mile. His report describes the geology and includes a bibliography of the geology of the surrounding region.

Taliaferro [2] has described the geology of the central Coast Ranges including San Benito County. Two of his published sections run from the Pacific Ocean eastward entirely through this county to the San Joaquin Valley. His section VI crosses the southern tip of San Benito County, entering from the west at a point where the San Andreas fault and the west county line practically coincide. At the San Benito River, a synclinal fold in the Cretaceous Asuncion group overlying the Jurassic Franciscan is shown. To the east is a mass of serpentine, then the New Idria thrust fault, east of which is a succession of Cretaceous and Tertiary

[1] Wilson, I. F., Geology of the San Benito quadrangle, California: California Div. Mines Rept. 29, pp. 183-270, 1943.

[2] Taliaferro, N. L., Geologic history and structure of the central Coast Ranges of California: California Div. Mines Bull. 118, pp. 119-163, 1943.

sediments. These show steep dips and even slight overturning near the fault, but the easterly dips become more gentle near the edge of the San Joaquin Valley. His section VII enters the central part of San Benito County at the Pinnacles, showing Miocene volcanic rocks overlying the basement complex of early Paleozoic or pre-Cambrian granite, gneiss, schist, and marble. To the east of the San Andreas fault zone are folding and faulting in Cretaceous and Eocene sediments, including a synclinal fold. Then the section passes through nearly 15 miles of the Jurassic Franciscan bounded on the east by the Ortigalito thrust fault. Cretaceous and Tertiary sediments extend from this point to the San Joaquin Valley. Dips are steep near the fault but gradually flatten toward the edge of the valley. The dips are to the east except immediately adjacent to the thrust fault.

Anderson and Pack [3] examined the geology of the west border of the San Joaquin Valley in connection with possible petroleum production in 1909-11. Their map shows the geology of about 200 square miles in southeastern San Benito County on a scale of 1:125,000, or about 2 miles to the inch. Cretaceous and Tertiary sediments predominate in the region, but a large area of serpentine is shown south of the New Idria quicksilver mine, and small areas of basalt near Llanada.

The geology of the Pinnacles National Monument has been described by Andrews.[4] It is an area of rocky crags, caves, columns, pillars, and deeply carved canyons on the western boundary of San Benito County at a point 38 miles south of Hollister. The strange land forms are the result of erosion in a series of Miocene volcanic breccias. The map accompanying Andrews' report shows not only the volcanic formations but also an equally large area of the basement complex to the west in Monterey County, through which are scattered numerous small lenses (0.1 mile, rarely 0.2 mile in diameter) of the Gabilan limestone.

Industries

Of the total acreage of 893,440 in San Benito County, 733,094 acres or 82 percent are privately owned, and 698,056 acres are in farms. The total value of farm products in 1939 was $4,169,285. The most valuable agricultural products are beef cattle and calves, sugar beets, apricots, prunes, and tomatoes. Important field crops are barley, wheat, and hay. The cultivation of garden seeds brings an income of about $100,000 per year.

Manufacturing operations include food processing and canning, preparation of feeds for animals, and the processing of garden and flower seeds.

MINERAL RESOURCES

Mineral production ranks below agricultural production in San Benito County, but in 1943 reached a war-time maximum of $3,528,642. The important products were quicksilver, portland cement, and miscellaneous stone. Other mineral products are antimony, asbestos, asphalt, bentonite, chromite, coal, dolomite, gems, gypsum, lime, limestone, manganese, magnesite, and mineral water. Mineral products are described in alphabetical order below, and production is listed in the accompanying table.

---

[3] Anderson, Robert, and Pack, R. W., Geology and oil resources of the west border of the San Joaquin Valley north of Coalinga, California: U. S. Geol. Survey Bull. 603, p. 220, 1915.

[4] Andrews, Philip, Geology of the Pinnacles National Monument: Univ. California, Dept. Geol. Sci., Bull. 24, pp. 1-33, 1940.

Mineral production of

Year	Quicksilver		Lime		Gypsum	
	Flasks	Value	Barrels	Value	Tons	Value
1865	[2]17,455	$943,617				
1866	6,525	346,673				
1867	11,493	527,529				
1868	12,180	559,062				
1869	10,315	473,459				
1870	9,888	567,373				
1871	8,180	516,158				
1872	8,171	538,714				
1873	7,735	621,353				
1874	6,911	726,899				
1875	8,432	709,553				
1876	7,272 [3]2,000	319,968 139,000				
1877	6,316	235,587				
1878	5,138	169,040				
1879	4,425	132,048				
1880	3,209	99,479				
1881	2,775	82,778				
1882	1,953	55,123				
1883	1,606	46,173				
1884	1,025	31,263				
1885	1,144	35,178				
1886	1,406	49,913				
1887	1,890	80,088				
1888	1,320	56,100				
1889	980	44,100				
1890	977	51,293				
1891	792	35,838				
1892	848	34,523				
1893	869	31,936				
1894	1,005	30,861	40,000	$44,000	762	$9,144
1895	1,100	36,000	41,000	41,000	750	8,250
1896	1,335	46,725	40,000	35,000	300	3,000
1897	3,605	135,185	25,000	18,500	300	2,000
1898	5,000	190,000			500	4,500
1899	4,780	245,000	16,600	18,675	100	700
1900	3,990	180,000	7,300	8,800		
1901	4,800	242,300				
1902	7,291	306,081				
1903	8,180	344,251				
1904	[5]8,480	314,000				
1905	7,764	279,651	15,000	15,000		
1906	7,203	262,909				
1907	7,675	292,878	8,453	8,453		
1908	9,600	405,792			2,000	8,000
1909	8,900	440,241			6,000	34,576
1910	10,800	488,700			12,000	50,000
1911	9,775	449,748			10,000	30,625
1912	9,743	409,596			8,000	32,000
1913	9,719	390,995			11,000	35,000
1914	6,633	325,349			7,000	21,000
1915	6,291	475,370				
1916	11,100	1,032,156				
1917	11,150	1,057,770				
1918	10,715	1,234,027				
1919	7,409	668,989				
1920	3,887	296,942				
1921	[6]					
1922	[6]					
1923	[6]					
1924	4,670	$320,758				
1925	6,085	486,797				
1926	[6]					

San Benito County, 1865-1945

Mineral water		Miscellaneous stone,[1] value	Miscellaneous and unapportioned		
Gallons	Value		Amount	Value	Substance
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	-----	-----	
-----	-----	-----	58 tons	$2,280	Antimony.
-----	-----	$19,000	-----	-----	
5,000	$300	6,000	2 tons	70	Antimony.
500	100	2,638	-----	-----	
900	450	[4]17,500	45 tons	135	Coal.
1,000	500	[4]25,240	19 tons	380	Asphalt.
10,000	3,750	13,000	100 tons	100	Limestone.
500	125	[4]12,794	-----	-----	
600	150	22,000	-----	-----	
10,000	400	23,200	-----	-----	
-----	-----	16,500	206 tons	2,472	Asphalt.
500	500	64,994	-----	-----	
2,600	3,120	23,000	-----	-----	
26,000	2,600	48,661	-----	-----	
26,000	2,600	63,220	-----	16,500	Gems.
3,120	1,560	83,709	-----	130,000	Unapportioned, 1900-1909.
3,500	1,400	94,243	-----	-----	
3,600	1,540	107,558	-----	-----	
26,000	1,240	83,232	-----	-----	
7,000	4,500	119,500	-----	-----	
700	280	110,630	-----	-----	
1,200	300	155,000	260 M 2,500 tons -----	1,560 9,500 335	Brick. Dolomite. Other minerals.
[6]	-----	155,250	8,100 tons -----	25,515 526	Dolomite. Antimony and mineral water.
[6]	-----	101,148	----- 7,000 tons	59,245 15,000	Antimony, chromite, magnesite, mineral water. Dolomite.
[6]	-----	103,295	130 tons 5,000 tons 5,340 tons -----	7,000 20,625 48,060 124,456	Chromite. Dolomite. Magnesite. Cement, manganese, mineral water.
[6]	-----	164,300	7,000 tons -----	24,500 418,687	Dolomite. Cement, magnesite, mineral water.
	-----	207,250	18,000 tons -----	57,750 921,082	Dolomite. Cement, magnesite, mineral water.
	-----	269,334	-----	1,116,759	Asbestos, cement, dolomite, magnesite, mineral water, quicksilver.
[6]	-----	$259,805	6,650 tons -----	$30,100 1,504,343	Dolomite. Asbestos, cement, magnesite, mineral water, quicksilver.
[6]	-----	424,854	-----	1,853,049	Asbestos, cement, dolomite, magnesite, mineral water, quicksilver.
[6]	-----	269,369	-----	1,554,476	Asbestos, cement, coal, dolomite, magnesite, mineral water.
-----	-----	351,363	-----	1,779,236	Asbestos, cement, dolomite, magnesite, mineral water.
-----	-----	328,460	-----	2,072,390	Antimony, asbestos, cement, dolomite, magnesite, mineral water, quicksilver.

Mineral production of

Year	Quicksilver		Lime		Gypsum	
	Flasks	Value	Barrels	Value	Tons	Value
1927	4,380	485,409				
1928	3,800	452,345				
1929	6					
1930	6		6			
1931	4,120	349,619	6			
1932	594	31,036	6			
1933	711	38,765				
1934	746	52,699				
1935	791	55,915				
1936	640	50.271				
1937	1,756	146,524				
1938	6					
1939	3,860	360,567				
1940	6,164	1,062,539				
1941	6,254	1,077,693				
1942	8,873	1,560,982				
1943	6					
1944	6					
1945	6					
Totals	394,604	$25,372,353	[6]193,353	$139,428	58,712	$238,795

[1] Includes crushed rock, rubble, rip-rap, sand, gravel.

[2] Production of New Idria mine from 1858-66; yearly details not obtainable, though New Idria began operation in 1850.

[3] Estimated output of Cerro Bonito, Monterey, and Stayton mines, 1870-77; yearly details concealed under heading of 'various mines' in early reports.

Antimony

Antimony occurs in the Stayton district, and the geology has been described in some detail by Bailey and Myers.[5] These writers estimate that the district contains several tens of thousands of tons of ore averaging about 1½ percent antimony.

The ore is found in veins mostly a few feet wide, but exceptional ones exceed 30 feet in width. They are quartz veins occupying northward-trending faults in basalt. Small lenses and pods of stibnite containing a few cubic feet of ore locally enrich the veins, which elsewhere contain only about 1 percent antimony.

The basalt in which this ore occurs is one unit of a Tertiary volcanic series covering an area of 100 square miles in the vicinity. Underlying rocks are black shale, greenish sandstone, chert, and greenstone, probably belonging to the Franciscan, and black shale, gray sandstone, and chert conglomerate probably Cretaceous. The Tertiary rocks, in addition to the basalt, include an overlying extrusive andesite, intrusive andesite, and intrusive rhyolite. The basalt is interbedded with a soft white to buff tuff that resembles sandstone.

Stayton mine consists of 900 acres of patented land in sec. 5, T. 12 S., R. 7 E., M.D., and adjoining sections on both sides of the county line between San Benito and Merced Counties. It is owned by R. B. Knox of Hollister, who states that 7 tons of ore were produced about 1941, running 30 percent antimony, from the Santa Clara claim on the San

[5] Bailey, E. H., and Myers, W. B., Quicksilver and antimony deposits of the Stayton district, California: U. S. Geol. Survey Bull. 931 Q, pp. 405-434, maps, 1942.

San Benito County, 1865-1945—continued

Mineral water		Miscellaneous stone,[4] value	Miscellaneous and unapportioned		
Gallons	Value		Amount	Value	Substance
------------	------------	371,050	------------	1,045,395	Antimony, asbestos, cement, mineral water, pyrite.
6	------------	6	------------	1,202,373	Cement, magnesite, mineral water, pyrite, miscellaneous stone.
------------	------------	6	------------	1,908,462	Cement, magnesite, quicksilver, miscellaneous stone.
------------	------------	6	------------	1,389,490	Cement, lime, magnesite, quicksilver, miscellaneous stone.
------------	------------	6	------------	304,665	Bentonite, gems (benitoite), lime, limestone, miscellaneous stone.
------------	------------	142,638	------------	26,250	Bentonite, limestone.
------------	------------	6	------------	208,714	Other minerals.
------------	------------	6	------------	214,158	Bentonite and miscellaneous stoue.
------------	------------	6	------------	187,239	Bentonite, miscellaneous stone.
------------	------------	6	------------	298,541	Bentonite, coal, miscellaneous stone.
------------	------------	6	------------	357,986	Bentonite, coal, dolomite, miscellaneous stone.
------------	------------	6	------------	527,192	Bentonite, coal, dolomite, quicksilver, miscellaneous stone.
6	------------	6	------------	186,526	Bentonite, dolomite, mineral water, miscellaneous stone.
------------	------------	6	------------	338,957	Dolomite, gems, miscellaneous stone.
------------	------------	6	------------	910,512	Antimony, cement, dolomite, miscellaneous stone.
------------	------------	6	------------	1,543,072	Antimony, cement, dolomite, miscellaneous stone.
------------	------------	6	------------	3,528,462	Cement, chromite, dolomite, manganese ore, quicksilver, miscellaneous stone.
------------	------------	6	------------	1,985,039	Chromite, dolomite, quicksilver, sand, gravel, crushed rock.
------------	------------	6	------------	1,949,386	Chromite, dolomite, quicksilver, sand, gravel, crushed rock.
[6]128,720	$25,415	[6]$4,259,735	------------	$29,908,550	

[4] Includes bituminous rock.
[5] Flasks of 76½ pounds previous to June, 1904; of 75 pounds thence, through 1927; of 76 pounds since January, 1928.
[6] See under 'Unapportioned.'

Benito side of the line. This claim adjoins the Pacific. Knox says that lenses of stibnite ore containing half a ton to a ton were found, but that so much lowgrade material separates the lenses that mining them does not pay. Five tons of similar ore running about 40 percent antimony were produced about the same time from French Ranch or Bishop mine 4 miles to the north. Quicksilver is more important at the Stayton mine, and the mine is described under that heading.

Asbestos

Simas Asbestos Property. Jack Simas, 2232 11th Avenue, Oakland, holds three claims, 60 acres, near the middle of sec. 25, T. 18 S., R. 11 E., M.D., on Picacho Creek, a tributary of San Benito River. It is 40 miles by road from King City, Monterey County, by way of Hernandez Valley.

In the summer of 1945, Simas was remodeling machinery on the property and adding equipment to produce about 5 tons per day of asbestos fiber, according to his estimate. The plant will consist of a 10-ton hopper feeding a series of shaking screens set on an incline. Above each screen will be a pair of rolls to reduce the size of the feed. The first rolls are 12 inches in diameter by 16 inches long and have raised corrugations on the faces about half an inch apart. First screen will allow material of ¼-inch size to pass through. Undersize will pass through the upper part of the screen, and above the lower end of the screen a suction device will remove asbestos fiber by means of a fan. Air and fiber will be discharged to a cyclone 4 feet in diameter by 8 feet high, where the fiber will settle out to the bottom of the cone and will be drawn off

for shipment. Three additional pairs of rolls with screens of successively finer sizes are to be installed, each equipped with a suction-fan and cyclone. The four primary cyclones will all discharge to a single large secondary cyclone, which in turn will discharge to a settling box about 20 feet long with a number of hoppers for drawing off different sizes of dust.

Rolls and screens will be driven by a tractor engine. Direct current generators of 10 kilowatt and 5 kilowatt driven by gasoline engines are on hand also. These will furnish power for the suction-fans, each of which is equipped with a 1-horsepower electric motor.

Mine workings consist of surface cuts of a maximum depth of 8 feet in loose serpentine probably the result of surface slides on the steep slopes. Considerable chrysotile asbestos in weathered fibers about ¼-inch long is to be seen in this loose material.

Barite

Small amounts of barite have been mined in San Benito County between 1915 and 1920 on Gabilan (Fremont) Peak. The main body of barite was on the Monterey side of the county line, but a small lens was mined to the north of the line also. The area is now within the Fremont Peak State Park, and a good road from San Juan Bautista is available.

Bentonite

D. Z. Stewart property in sec. 30, T. 15 S., R. 7 E., M.D., was worked for bentonite in 1939 and several earlier years by A. P. Stewart, 1015 Vermont Street, San Jose. The address of the owner, D. Z. Stewart, was 231 Dennett Avenue, Fresno. The deposit is shown on the geologic map of the San Benito [6] quadrangle, and a second deposit is shown to the southeast in sec. 33 of the same township. Both are found with tuffaceous formations of the Miocene volcanics.

Cement

Pacific Portland Cement Company, 417 Montgomery Street, San Francisco, owns the cement plant near San Juan Bautista formerly operated by Old Mission Portland Cement Company. The plant was closed in June 1943 and was idle at the time field work was done for the present report in 1945.

Chromite

Although numerous occurrences of chromite are known in the serpentine belt south of Idria, no large lenses have been found, and production has been small. Several carloads of float were shipped about 1875.

Aurora mine in sec. 5, T. 18 S., R. 12 E., M.D., is owned by Paul Wingert of Idria. It is a former quicksilver producer but was not being mined for that metal in 1945. E. T. Haun produced a little chrome ore of good grade from the serpentine on this property in 1944. It ran 55.18 percent Cr_2O_3, and had a chronium to iron ratio of 3.613 to 1.

Clay

Alpine Quicksilver Mining Company in 1915 burned about 260,000 brick in field kilns on lower Clear Creek near Hernandez using local clay. They were used in building a furnace for treating quicksilver ore.

[6] Wilson, Ivan F., op. cit.

Other occurrences of clay in the county are mentioned by Dietrich[7] in Bulletin 99 of the California State Division of Mines, to which reference should be made for further information.

Coal

Chemi-Coal Products Company (Mascovich mine), P. O. Box 181, King City, a partnership of Mr. and Mrs. R. L. Russell, King City, Mrs. Frances Mascovich, Salinas, and Dr. F. F. Slater, Salinas, holds 320 acres of patented land in secs. 20 and 21, T. 17 S., R. 10 E., M.D., 26 miles from King City by road. Five miles of mountain road near the mine have recently been resurfaced with gravel by Russell, starting at a ford crossing San Benito River, and running up James Creek. The remainder of the road to King City is oiled.

The coal on this property was opened by a slope in 1870, and about 1907 was leased by Monterey Coal Company. A few details on these early workings are given by Laizure.[8]

At the present time (1945), the coal is opened by means of an adit driven westward 400 feet to the coal with drifts 240 feet to the north and 222 feet to the south. From the 120-foot point in the north drift a raise has been driven on the coal to the surface, a distance of 325 feet. The coal shows a width of 6 feet, practically free of clay partings and appears to be of good quality. The strike in present workings is a few degrees east of north, but the seam is curved slightly so that the north drift is gradually being turned to a direction more nearly due north. Dip is 33° to the west. The hanging wall is soft slate for a thickness of about 6 inches. Above the slate is a hard conglomerate containing pebbles an inch in diameter, and this stands very well in the workings. The footwall where cut by the adit is clay for a thickness of 10 to 12 feet. The remainder of the adit is in sandstone, which stands without timber. According to Russell, the outcrop of the coal can be traced for 3,500 feet on the surface, and the run-of-mine coal contains 48 percent fixed carbon, $2\frac{1}{2}$ percent sulphur, 8 to 11 percent moisture, 5 to 7 percent ash, and yields 12,500 B.T.U. per pound.

At a point on the main highway, a quarter of a mile south of King City, the company has a briquetting plant under construction with a rated capacity of 40 tons of briquettes in 8 hours. Coal will be crushed by rolls to pass a $\frac{1}{4}$-inch screen then conveyed to a storage-bin. From the bin a conveyor will deliver it to a preheater and mixer where about 0.5 percent each of asphalt and rosin (based on the weight of the coal) will be added. A bucket-elevator will lift the mixture to a bin, from which it will be fed to a briquetting press making 50 briquettes per stroke. Briquettes will be cylindrical, $2\frac{5}{8}$ inches in diameter by 3 inches long.

San Benito coal mine is in T. 17 S., R. 11 E., M.D., near the Ashurst ranch on Larius Creek. A little sub-bituminous coal was mined here about 1906 and sold to the New Idria Quicksilver Mining Co. A. D. Lane, 8721 B Street, Oakland, California, states that he is planning to re-open the mine.

Dolomite

Hamilton Mines consist of two tracts of land in what would be sec. 2, T. 14 S., R. 5 E., M.D., if the regular land-net were projected

---

[7] Dietrich, W. F., Clay resources and ceramic industry of California: California Div. Mines Bull. 99, pp. 190-193, 1928.

[8] Laizure, C. McK., San Benito County: California Div. Mines Rept. 22, p. 230, 1926.

northward 2 miles into a Spanish grant. The tract on which the present quarry and mill are located contains 80 acres and the second tract to the south, known as the O'Hara tract, contains 400 acres. A. E. Hamilton, P. O. Box 621, Hollister, is owner and operator.

The mill is on the west end of the 80-acre tract, and the present quarry and 125-ton bunker are on the east end. Dolomite is hauled $1\frac{1}{2}$ miles by truck from the bunker to the mill. At the bunker, an adit level 300 to 400 feet long has been driven in the dolomite. At 150 feet from the portal a raise goes up to the quarry floor above, and this provides a storage-capacity of 125 tons. The depth of this adit-level below the surface is 115 feet, but the total thickness of dolomite at the raise is 240 feet. At the same point where the raise is located a crosscut has been driven southward for 100 feet in dolomite.

The mill is a crushing and screening plant with a capacity of 400 tons in an 8-hour day. Present output is about 400 tons per week. For steel furnaces the dolomite is screened through a $\frac{3}{4}$-inch screen, and material below 4-mesh is screened out and stock-piled. For chemical plants it is screened through $\frac{3}{4}$-inch and everything below $\frac{3}{8}$-inch is screened out. The mill is 10 miles by road from Hollister. Hamilton is planning an extension of this mill to enable him to make pulverized limestone from a deposit a few miles to the south. It is mentioned below in the section on limestone.

In 1944, the sum of $11,000 was spent in developing and sampling the O'Hara tract. Overburden was removed by means of a bulldozer from cuts about 50 feet apart, and five churn-drill holes were put down to a maximum depth of 100 feet. Hamilton states that this work indicates a body of dolomite of 6,000,000 tons running about 21 percent magnesia and less than 0.5 percent silica.

Gems

Dallas Mining Company, R. W. Dallas, Trustee, Box 205, Mendota, California, holds two patented lode claims, 40 acres, in secs. 24, 25, T. 18 S., R. 12 E., M.D., covering the only known deposit of the gem-mineral benitoite, which resembles the sapphire. However, benitoite occurs in many shades of blue, ranging down to colorless. The deposit strikes to the northeast and dips 60° to 70 ° NW. It was opened by a cut, from which a 40-foot adit was driven. A shaft was put down to a depth of 25 feet in the footwall of the deposit near the open cut. From the bottom a crosscut was driven for about 60 feet through the mineralized zone. Dallas states that the zone had a width of about 4 feet at this depth. The shaft has caved so that the crosscut is now covered and inaccessible. The mine was shut down in 1912, and seven boxes of powder were left on the property. Later some vandal set all of this off in the adit and collected considerable benitoite from rock scattered by the explosion.

The largest stone found weighed $7\frac{7}{8}$ carats after cutting and was without flaws. Dallas still holds about 3,000 carats of the small blue stones. He is open to negotiations with persons who wish to re-open the mine. Details of the mineralogy of benitoite and associated minerals have been published by Louderback.[9]

[9] Louderback, G. D., Benitoite, its paragenesis and mode of occurrence: Univ. California, Dept. Geol. Sci., Bull. 5, pp. 331-380, plates 27-39, 1909.

A, HAMILTON DOLOMITE QUARRY, SAN BENITO COUNTY, CALIFORNIA

B, HAMILTON DOLOMITE QUARRY MILL

Gypsum

A large tonnage of gypsum has been produced in San Benito County but some of it has been credited to Monterey County because of shipment from King City, and probably some of it has not become of record. In addition to the active locality mentioned below, gypsum has been noted in the following sections and has been mined from some of them: sec. 15, T. 18 S., R. 9 E., M. D.; secs. 11 and 32, T. 18 S., R. 10 E.; sec. 5, T. 19 S., R. 10 E.

Monterey Gypsum Company is a partnership of Walter Wilkinson, Salinas, H. B. Scott, P. O. Box 900, Watsonville, and J. Wilkinson, Watsonville. J. C. Billadeau, Box 367, King City is superintendent. Gypsum is being mined on land owned by Tannehill Cattle Company near the Bitterwater road, 14 miles east of King City, Monterey County, in the Rancho San Lorenzo (Sanchez). Present operations would be in secs. 17 and 18, T. 18 S., R. 9 E., M.D. if the survey of that township were extended into the rancho. This part of the property is known as the Mule Shoe ranch. The property has produced gypsum during several other periods such as the years 1898, 1907, and 1913-14. Some of the production was probably credited to Monterey County because shipments were made from King City.

Gypsum is found in flat-lying lenses 4 to 6 feet thick covered by 4 to 8 feet of overburden. The lens now (1945) being mined contained 44,000 tons including gypsite. It occurs near the top of a low ridge. Overburden is removed, then the gypsum is blasted and loaded with a $\frac{3}{4}$-cubic yard diesel power shovel on a truck, which hauls 6 cubic yards per trip to the new processing plant about half a mile away.

The gypsum is crushed to 4- to 6-inch size in a 15- by 38-inch jaw crusher; then conveyed to a Gruenler hammer mill, which pulverizes it so that about 30 percent passes a 100-mesh screen. The pulverized gypsum is elevated to a 14-foot Raymond air-separator, the product of which is 90 percent through 100 mesh. Oversize is returned to the hammer mill. The product from the separator is elevated to two storage bins each of 40-ton capacity. Under the No. 1 storage bin is a 3-tube Bates sacker, with which ground gypsum is sacked for shipment. Under the second 40-ton bin is a 12-inch screw feeding automatic hopper scales. A one-ton hopper is loaded and dumped into a truck for bulk-shipments. Capacity of the plant is 200 tons for 8 hours. The gypsum is sold for agricultural use and is guaranteed to run 85 percent $CaSO_4.2H_2O$.

Lime and Limestone

Massive crystalline limestone suitable for the manufacture of lime and cement and for other industrial purposes outcrops along the Gabilan Range from San Juan Bautista to the region around Pine Rock in T. 16 S., R. 8 E., M.D. In places the limestone is dolomitic. Only a few of the more important deposits are mentioned below. See also the section on dolomite.

Hamilton Deposit. A. E. Hamilton, Post Office Box 621, Hollister, is planning to produce limestone from a deposit in sec. 23, T. 14 S., R. 5 E., M.D. The limestone will be pulverized in an extension of the plant where he now crushes dolomite, and which is described herein under the heading of dolomite. He states that the limestone crops out on 25 acres with a face 45 feet high opened in one place, and that it runs 99 percent $CaCO_3$. Lime

was at one time burned in two kilns which have been on the property since 1890.

Henry Cowell Lime and Cement Company, 2 Market Street, San Francisco, has held large tracts of land for limestone in secs. 28, 29, 30 and 32, T. 14 S., R. 6 E., M.D., and secs. 14 and 24, T. 14 S., R. 5 E., about 13 miles from Tres Pinos. About 1900, Cienega Lime Company operated four kilns of 50-barrel capacity each on this property, but no production has been made recently.

McPhail Deposit. Amy McPhail of Hollister holds 81 acres in sec. 23, T. 14 S., R. 5 E., M.D., 14 miles southeast of Tres Pinos, and a one-third interest in a 41-acre tract in sec. 13 of the same township. Other owners of the 41-acre tract are A. Jose, 5904 MacArthur Boulevard, Oakland, and U. G. Harlan, Hollister. The 81-acre tract contains a bold outcrop of limestone standing 150 feet high in places. Analyses show 96 percent $CaCO_3$ and 2½ to 4 percent $MgCO_3$.

Pacific Portland Cement Company, 417 Montgomery Street, San Francisco, has quarried large amounts of limestone near its cement plant at San Juan Bautista. A quarry operated in this connection is 4 miles by road south of the plant, and the stone was delivered by truck. Formerly a railroad of 36-inch gauge was used. The cement plant was shut down in June 1943.

San Benito lime deposit (Connelly and Kruse) of 243 acres in sec. 23, T. 14 S., R. 5 E., M.D., adjacent to the McPhail holdings, is assessed to Walter R. Fontaine, 244 Lakeside Drive, Oakland.

Magnesite

Large quantities of magnesite were produced from the summit of a high spur running westward from Sampson Peak, in the years 1917-26, but nothing has been done with this deposit recently. Further particulars are contained in Division of Mines Bulletin 79.[10]

Sampson magnesite mine (Maltby No. 3 mine), 288 acres in secs. 26, 27, 34 and 35, T. 17 S., R. 11 E., M.D., was assessed in 1945 to Chas. F. Bulotti, 829 Folsom Street, San Francisco.

Manganese

Bulletin 125 of the Division of Mines[11] lists seven places in San Benito County where manganese ore has been found. The total production of the county is listed in this bulletin (1943) at 246 tons. Only the two properties described below were active during the war of 1941-45.

Hendricks mine in sec. 24, T. 13 S., R. 8 E., M.D., produced a small tonnage of manganese ore in 1943, which was sold to Metals Reserve Company, purchasing agent for the United States government.

McCreary Ranch mine in sec. 29, T. 14 S., R. 9 E., M.D., was being developed in 1943 under a lease held by R. R. Stephenson, 548 Glenview, Oakland. Lenses in Franciscan chert were being prospected by

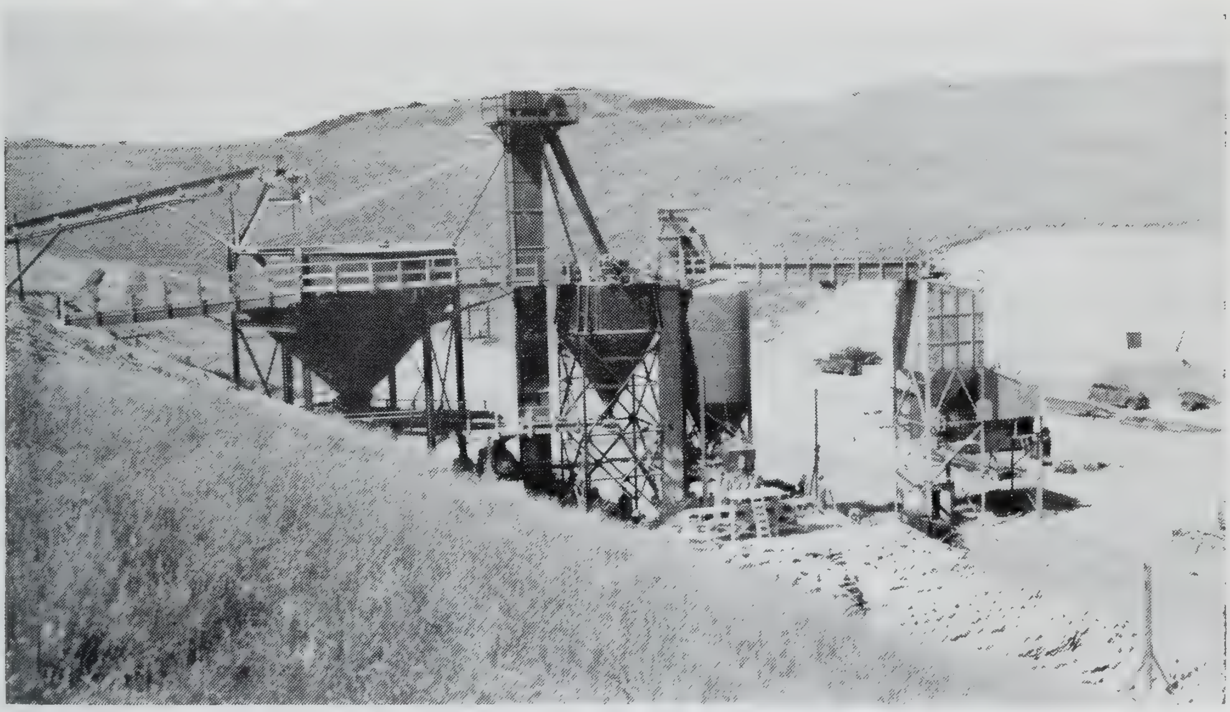
---

[10] Bradley, W. W., Magnesite in California: California Div. Mines Bull. 79, pp. 66-71, 1925.

[11] Jenkins, O. P., and others, Manganese in California: California Div. Mines Bull. 125, pp. 83-84, 158-159, 1943.

Bradley, W. W., and others, Manganese and chromium in California: California Div. Mines Bull. 76, pp. 60-61, 94-95, 1918.

A, MONTEREY GYPSUM COMPANY, SAN BENITO COUNTY, CALIFORNIA
Loading from flat deposit.



B, MONTEREY GYPSUM COMPANY GRINDING PLANT

PACIFIC PORTLAND CEMENT COMPANY LIMESTONE QUARRY
SAN BENITO COUNTY, CALIFORNIA

means of open cuts. Hand-sorted ore contained over 50 percent manganese and was chiefly of the hard blue-black psilomelane type, somewhat porous. A few additional details are given by Wilson.[12]

Mineral Water

San Benito Mineral Water Company is being organized by Mrs. Ruby Flautt, Route 1, Box 306, Hollister, to develop mineral water for baths and sale of drinking-water. Mrs. Flautt holds a lease on 10 acres of land in sec. 7, T. 13 S., R. 6 E., M.D., 4 miles southeast of Hollister owned by Mrs. E. J. Anderson, Gilroy, on which is a well 286 feet deep drilled about 1890. Water rises to within 100 feet of the surface and is pumped from that depth. The paved highway from Hollister to Tres Pinos passes the property, and one of the stage-lines running from San Francisco to Los Angeles maintains a flag-stop there. Following is an analysis of the water by M. R. Jaffa of the University of California made in 1894:

Constituents in parts per million:	By weight
Sodium (Na), Potassium (K)	780
Calcium (Ca)	29
Magnesium (Mg)	18
Iron (Fe)	8.9
Sulphate (SO_4)	736
Chloride (Cl)	566
Carbonate (CO_2)	178
Silica (SiO_2), organic matter and combined water	188
	2,503.9

Petroleum

Bulletin 118 of the California Division of Mines[13] shows that 35 wells ranging in depth to 5,200 feet have been drilled in San Benito County in a search for petroleum. A few of these, including the deepest, were drilled near the northwest county line in an effort to locate an extension of the Sargent oil field, just across the line in Santa Clara County, which has a small commercial production of petroleum. The geology has been described by Allen.[14]

Many wells were drilled in the southeastern part of the county in the area investigated by Anderson and Pack.[15] Indications of possible commercial amounts of petroleum have been found in this region, including an 80-foot dug well, from which about 5 barrels of oil of 36° Baume gravity was pumped with a hand pump each day for several days in succession. However, the structures in the Tertiary formations are monoclinal or synclinal. No large domes or anticlines, which are favorable to the accumulation of large amounts of petroleum, have thus far been located in the Tertiary formations of San Benito County.

Quicksilver

Alpine mine in secs. 13 and 14, T. 18 S., R. 11 E., M.D., is held as unpatented mining claims by Harry A. Leonard of Hollister, who has made a contract for its sale.

[12] Wilson, Ivan F., Geology of the San Benito quadrangle, California: California Div. Mines Rept. 29, p. 265, 1943.
[13] Jenkins, Olaf P., and others, Geologic formations and economic development of the oil and gas fields of California: California Div. Mines Bull. 118, p. 654, 1943.
[14] Allen, J. E., Geology of the San Juan Bautista quadrangle, California: California Div. Mines Bull. 133, pp. 73-74, 1946.
[15] Op. cit.

Aurora mine is in sec. 5, T. 18 S., R. 12 E., M.D., in the New Idria district, and was owned in 1941 by North American Mining Company, Boston, Massachusetts. Details of the geology and workings have been described by Eckel and Myers.[16] Although some production was made in 1943, the mine was idle when visited that year and also in 1945.

Bitter Water mine is in sec. 25, T. 15 S., R. 9 E., M.D., 2 miles southwest of Llanada and is owned by H. V. Underwood and E. A. Matthews of Hollister. A few flasks of quicksilver were produced in 1932 and 1938, but the mine has been inactive recently. Workings are about 100 feet in length.

Bradford, see Cerro Gordo.

Breen group owned by the Breen Estate of Hernandez is in sec. 31, T. 18 S., R. 12 E., M.D., and sec. 36, T. 18 S., R. 11 E. The mine has a total of about 300 feet of workings and was last active in 1933.

Cerro Bonito mine is about 2 miles south of Llanada in sec. 31, T. 15 S., R. 10 E., M.D., and sec. 6, T. 16 S., R. 10 E., and consists of patented land held by Cerro Bonito Quicksilver Mining Company of which Thomas Flint of Hollister is president. Dan. A. Williams of Salinas held a lease in 1941.

The mine is one of the oldest in the county but was operated only from 1873-76. During that time a production of more than 800 flasks of quicksilver is reported to have been made. Eckel and Myers [17] have published about a page on the geology.

Cerro Gordo mine (Bradford) is 15 miles west of Llanada in secs. 3, 4 and 9, T. 15 S., R. 8 E., M.D. An old brick furnace stands on this property, but no production has been made, so far as is known. Dan A. Williams of Salinas held a lease in 1941, but the property was idle when visited in 1945.

El Rey mine is a quarter of a mile northwest of the Lucky Strike mine in sec. 12, T. 15 S., R. 9 E., M.D., and is owned by Manuel Perry. Between 1940 and 1943, about 60 flasks of quicksilver were produced. Sketch maps of workings of a total length of about 300 feet may be found in an earlier report.[18]

Flint group including the Andy Johnson, Clear Creek, Fourth of July, and Red Rock mines is in secs. 2, 11, 12 and 18, T. 18 S., R. 12 E., M.D., and sec. 11, T. 18 S., R. 11 E., and is owned by W. C. Webster of Hernandez. Workings amount to about 1,500 feet, and the last production was made in 1942.

Florence Mac mine is in sec. 32, T. 18 S., R. 12 E., M.D., and is held by L. H. Burns of King City and Arthur Hoag of Hollister. Workings amount to about 900 feet, and the last production was made in 1939.

Lea-Grant mine is 8 miles southeast of Llanada in secs. 1, 2, 11 and 12, T. 16 S., R. 10 E., M.D., and is owned by Lily Berg of Hollister.

[16] Eckel, E. B., and Myers, W. B., Quicksilver deposits of the New Idria district, San Benito and Fresno Counties, California: California Jour. Mines and Geology, vol. 42, pp. 108-109, 1946.
[17] Op. cit.
[18] Yates, R. G., and Hilpert, L. S., Quicksilver deposits of central San Benito and northwestern Fresno Counties, California: California Jour. Mines and Geology, vol. 41, pp. 11-35, 1946.

Production from 1941-43 amounted to 706 flasks of quicksilver, which was produced with a 50-ton rotary furnace. A description of the geology and a geologic map of the area have already been published.[19]

Lone Oak mine is in sec. 7, T. 15 S., R. 10 E., M.D., about half a mile west of the Valley View mine, and is owned by Mrs. Frank McCollough of Hollister. Workings consist largely of surface pits and trenches over a distance of 400 feet. About 50 flasks of quicksilver have been produced with retorts.

Lucky Strike mine is in sec. 12, T. 15 S., R. 9 E., M.D., 2 miles northwest of Llanada, and is on land owned by Mrs. Rose H. Garcia. James E., George W., and Claude E. McIntyre of Hollister held a lease from 1941-42 and produced between 200 and 300 flasks of quicksilver with two retorts containing six tubes. The property was inactive in 1944 and 1945. A description of the geology and maps of the 1200 feet of workings have already been published.[20]

New Idria mine [21] has been for some time the largest producer of quicksilver in the United States, although its total production has not yet reached that of the New Almaden mine in Santa Clara County to the northwest. New Idria Quicksilver Mining Company operates the mine at Idria under the management of Henry W. Gould, Mills Building, San Francisco. At Idria, C. Hyde Lewis is general superintendent, Wesley Shadduck is general foreman, E. A. Green is office manager and purchasing agent, R. A. Crippen is geologist, and Max Daugherty is engineer. The property includes the Idria, Sulphur Springs, Molino, and San Carlos groups of patented claims, 81 acres, in secs. 28, 29, 32 and 33, T. 17 S., R. 12 E., and secs. 3 and 4, T. 18 S., R. 12 E., M.D., and 4,210 acres of additional patented land. The distance by road from Hollister is 67 miles, and from Mendota, Fresno County, is 55 miles. The elevation ranges from 2,500 to a little more than 5,000 feet.

The first recorded production was in 1854, and the history of the earlier operations has been described by Becker, Forstner, Bradley, Moorehead, Ransome and Kellogg, and others.[22] Bradley gives a sketch of the main ore-zone showing that it had the shape of the crescent on the lower levels with the convex side toward the south. The length was 1,200 feet on the 10th level, and the width was at a maximum of 235 feet on the 5th level, where the length was 800 feet. The rock of this zone was not all ore, but various veins and impregnations were found within it.

Ore bodies now being mined are not within the zone, but are to the southeast of it. The mineralization is believed to be controlled largely by a fault on which Franciscan rocks of probable Jurassic age are thrust over shales and sandstones of the Panoche formation of Cretaceous age. The fault strikes southeastward and dips about 50° SW. The 10th level

[19] Yates and Hilpert, op. cit., pp. 28-29.

[20] Yates and Hilpert, op. cit., pp. 32-33.

[21] See also *Condenser Installation at the New Idria Quicksilver Mining Company, Idria, California,* by Richard A. Crippen, Jr., which follows this report, pp. 61-62.

[22] Becker, G. F., Geology of the quicksilver deposits of the Pacific Slope: U.S. Geol. Survey Mono. 13, pp. 301-309, 1888.

Forstner, Wm., The quicksilver resources of California: California Min. Bur. Bull. 27, pp. 138-145, 1908.

Bradley, W. W., Quicksilver resources of California: California Min. Bur. Bull. 78, pp. 107-120, 248-250, 1918.

Moorehead, W. R., Methods and costs of mining quicksilver ore at the New Idria mine, San Benito County, Calif.: U.S. Bur. Mines Inf. Circ. 6462, pp. 1-14, 1931.

Ransome, A. L., and Kellogg, J. L., Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, pp. 421-428, 1939.

adit of the New Idria mine (elevation 2,714 feet) which is the main haulage level and the portal of which is near the furnace-plant, runs southwestward for 3,086 feet to strike the overthrust fault. Most of the ore has been found to the southeast of this point, but the maps show considerable old development to the northwest, and on the 5th level to the northwest an ore body, which was stoped long ago. Using this point where the 10th level strikes the fault as a reference point, it can be seen that ore has been found near the surface at the Sulphur Springs mine 2,000 feet to the southeast, at the Molino 3,000 feet still farther to the southeast, and at the San Carlos 3,600 feet to the southeast beyond the Molino. Main levels of the New Idria mine on which ore is being mined and their elevations follow: 4th, 3,333 feet; 5th, 3,252 feet; and 6th 3,152 feet.

The principal new ore body at the New Idria mine is about 500 feet southeast of the glory hole. The mineralization is controlled by the same overthrust fault mentioned above, but this apparently has been offset several hundred feet to the east by a series of faults known as the Five-east faults that strike N. 45° E. to N. 80° E. and dip about 60° S. They are believed to be pre-mineral normal faults with considerable horizontal displacement, but exact direction and amount of the movement are not yet known. A third series of faults striking N. 10-20° E. with dip about vertical is believed to be post-mineral. The shattering of the indurated shales and sandstones of the Panoche formation together with the traps formed by gouges of different strands of the overthrust fault and closed by gouges of strands of the Five-east series of faults are thought to have produced conditions favorable to the deposition of the ore, which consists of cinnabar deposited in cracks and fractures of the shale and sandstone. Some silification and pyrite are present also. The ore body is in the form of an irregular lens with a maximum length of 200 feet and width of 50 feet between the 5th and 6th levels. It is about the same size on the 4th level but pinches about 45 feet vertically above the 4th. It goes down as far as the 6th level in spots but not as a continuous ore body.

New ore has been discovered at a point 350 feet southeast of the ore body mentioned in the last paragraph on an intermediate between the 4th and 5th levels. This ore is being followed in a northwesterly direction, and a connection may be found between the two ore bodies. The hanging wall strand of the overthrust fault zone flattens here so that it intersects the footwall strand a little below the 3rd level. This intersection together with a closure by a strand of the Five-east system of faults formed the trap for the mineralizing solutions.

The new ore bodies mentioned above are on the footwall side of the crushed zone caused by the overthrust fault, but ore has been found recently on the hanging-wall side also. This ore was found at a point below the 6th level where the hanging wall has a dip of only about 30°, which would cause it to intersect the footwall about half way between the 4th and 3rd levels. This was recognized as a probable trap for mineralizing solutions, and raises were put up at intervals of 25 feet from an intermediate level called the 6½ to locate the ore. One of the Five-east series of faults is a factor in closing this trap also. In May 1945 this ore body had been opened for a length of 70 feet and width of 10 feet, but good ore was still showing in the side and end of this working, and the boundaries of the ore body had not yet been exposed.

The importance of shattered rock and structural traps in localizing cinnabar ore has been emphasized by Schuette.[23] The block diagram showing mine workings and geology on isometric projection has been found very useful at the New Idria mine in detecting possible traps for the mineralizing solutions. A special instrument developed at this mine for drawing isometric projections has been described by Forbes.[24] Further details of the geology of this mine and the district in which it is located, including maps of both the surface and the underground workings, may be found in the report by Eckel and Myers.[25]

The square-set system of mining is used with sets 5 by 5 by 7½ feet high. Because of the crushed condition of the rock, only a few sets along the strike of the veins and a few sets at a right angle are opened at one time. These are filled with waste before adjacent ground is opened. The use of shoveling machines and slusher scrapers has been extended so that practically no shoveling by hand is done in the mine. A slusher-raise about 400 feet long on an angle of 22 degrees from horizontal is in use between the 5th level and the 6½-level. At the 6½-level ore is dumped by the slusher scraper into a steep raise through which the ore flows by gravity to the 10th level. This raise has a compartment for ore, one for waste, and a manway provided with a skip. On the 10th level ore is hauled to the furnace plant in cars drawn by a storage battery locomotive. An aerial cable tramway that formerly transported ore from the 5th level is not in use.

H. W. Gould installed the first rotary furnaces used for the production of quicksilver from cinnabar ore at the New Idria mine in 1918. This was an adaptation of the rotary cement kiln, and the installation was described by Bradley.[26] Four of the original furnaces are still in use, but they have been extensively remodeled to reach their present state of efficiency, and the condensing system for two of them is being further remodeled at this time (1945). Furnaces of this and other types in use at quicksilver mines have been described recently by Gordon I. Gould.[27]

At the New Idria mine, ore crushed to 2½-inch size is fed to the furnaces, which are steel cylinders 5 feet in diameter by 56 feet long lined with fire brick. They are set on a grade of about ½-inch per foot to cause the ore to flow from the upper to the lower end, and turn at one revolution in 42 seconds. Firing is done at the lower end with fuel oil atomized with high-pressure air. Pre-heated air to give an excess of oxygen is drawn over the hot rejects in a concrete bin below this end of the furnace. Ore is fed at the upper end of the furnace; hence the hot gases of combustion and the stream of ore are flowing in opposite directions. The furnaces have a capacity of about 125 tons each per 24 hours.

The feeder consists of a shaking pipe about 10 inches in diameter set on a grade of about 1½ inches per foot. One end enters the furnace through a seal in which the pipe can slide, the other end receives ore

---

[23] Schuette, C. N., The geology of quicksilver ore deposits: California Jour. Mines and Geology, vol. 33, pp. 38-50, 1937.

[24] Forbes, J. McLaren, The isometrograph as developed and used at the New Idria quicksilver mine: California Jour. Mines and Geology, vol. 39, pp. 367-376, 1943.

[25] Eckel, E. B., and Myers, W. B., Quicksilver deposits of the New Idria district, San Benito and Fresno Counties, California: California Jour. Mines and Geology, vol. 42, pp. 81-124, 1946.

[26] Bradley, W. W., op. cit. pp. 248-250.

[27] Gould, Gordon I., Modern plants for reduction of quicksilver: Am. Inst. Min. Met. Eng. Trans., vol. 159, pp. 471-486, 1944.

from a small chute in the fine-ore bin. A cam forces the pipe back toward the bin, and a spring draws it toward the furnace, where it stops with a bump. The ore inside the pipe keeps traveling, and is thus fed to the furnace. The speed is adjustable by altering the speed of the cam.

Exhaust fans draw the gases, including the vaporized quicksilver, from the furnaces through cyclone dust collectors and discharge them to the condensing system of 16-inch cast-iron pipe followed by redwood tanks 10 feet in diameter by 20 feet high and a stack discharging to the atmosphere.

The cast-iron pipes are placed vertically with two 12-foot lengths in each stand followed by a return bend to connect it with the next stand. For the two furnaces in operation in the spring of 1945, the condensing system contained 132 lengths of pipe each 12 feet long, followed by two of the 10- by 20-foot redwood tanks. Normally three of these tanks would be used but one had been cut out because of the remodeling of the plant. The number of them needed depends on the amount of dust in the ore.

The cast-iron pipes discharge condensed quicksilver through openings in the bottom which are submerged in water contained in rubber buckets. The buckets are emptied periodically by hand. The lower ends of the redwood tanks contain bottoms in the form of an inverted cone, 5 feet high, and these drain to rubber buckets also. Covered hand-holes in the top return bends of the cast-iron pipes provide a means of washing them down with a hose.

Much of the material in the buckets consists of soot containing minute globules of quicksilver that are coated in such a way that they will not coalesce into a pool of liquid quicksilver. At most quicksilver mines the dried soot mixed with lime is hoed by hand with an ordinary garden-hoe to destroy the coating and make the globules unite. At New Idria a machine is provided for this purpose. It consists of a circular pan 6 feet in diameter and 1 foot deep provided with rabble arms such as are used on a roaster. Four arms are each provided with three scrapers, and the arms revolve at 4 to 5 revolutions per minute. Beneath the pan is a water-bath 4 inches deep electrically heated to dry the soot. Liquid quicksilver discharged from a small hole in the side of this machine flows to a storage-tank, through a weighing device, and into flasks for shipment.

The new condensing system of 136 lengths of cast-iron pipe each 12 feet long now (1945) being installed on the two furnaces not in operation provides such a machine for hoeing the soot directly below the condensers; the machine ejects the dried soot mechanically and thus does away with the hand-labor of collecting it in buckets. The cast-iron condensing system is being mounted on top of a circular concrete tray 25 feet in diameter by 15 inches deep at the edge. A well is provided in the center to carry a vertical shaft to support raking arms like those of a thickener. The bottom slopes from both the well and the edge to a discharge ring 20 inches deep midway between the well and the edge. The hoeing machine below will have arms attached to the same shaft as the thickener arms. The shaft will turn at one-quarter of a revolution per minute.

New Tirado mine is in sec. 31, T. 18 S., R. 12 E., M.D., and is owned by S. Tirado of Hernandez. The total length of workings is about 100 feet. Cinnabar has been found in indurated shale of the Panoche formation.

Parker Carlson mine is in sec. 13, T. 15 S., R. 9 E., M.D., 2 miles northwest of Llanada and is owned by Mrs. Frank McCullough of Hollister. G. B. Parker and G. E. Carlson of Hollister held a lease in 1941. Several flasks of quicksilver have been produced from small pockets of cinnabar ore found along a fault that dips about 30° E.

Picacho mine (Ramirez Consolidated), is in secs. 19 and 20, T. 18 S., R. 12 E., M.D., and is owned by Hernandez Quicksilver Mining Company of Hernandez. A small production was made each year for several [28] years up to 1916; also in 1940. Cinnabar occurs in association with silicified zones in serpentine.

Stayton quicksilver mine consists of 900 acres of patented land owned by R. B. Knox of Hollister in sec. 5, T. 12 S., R. 7 E., M.D., and adjoining sections. Mineralization follows a fault zone striking northward and dipping 56° W. at the 70-foot level but steeper below the 150. Knox states that stopes extend almost continuously for a length of 150 feet and width of 12 feet below the 70-foot level. This is an adit-level 70 feet below the blacksmith shop or the collar of an old 250-foot shaft now dismantled. Nearly all of the workings are inaccessible below the 70-foot level.

Ore mined recently has come partly from a pillar left near the old shaft but mostly from a system of stringers and pipes in the hanging wall of the main vein. A gouge separates this stringer-zone from the main vein, and no direct connection of the mineralization in the stringers with the mineralization in the main vein has yet been established although the workings are within a few feet of each other in places.

Country rock where exposed in the workings is basalt, but andesite occurs in the vicinity also. Details of the geology are contained in Bulletin 931-Q of the U. S. Geological Survey. A few notes and reference are given above under the heading of antimony.

Ore running from 8 pounds to 30 pounds per ton in quicksilver is produced by Knox and one other man by careful selective mining and hand-sorting. Only hand-tools are used. Quicksilver is recovered in a retort near the portal of the 70-foot level.

The retort consists of two 13-inch pipes 7 feet in length set in a furnace insulated with 2 inches of rock wool. This effects a great saving in fuel. The 3-foot arch over the pipes was poured of concrete made from burned ore, crushed fire-brick, and a refractory cement made by Atlas Lumnite Cement Company. This has given good service. Capacity of the retort is one ton per 24 hours. Each charge is retorted for 12 hours. One gallon of stove oil is burned per hour. The property is partly in Merced County, but production has been credited to San Benito County.

The Pacific claim of this group, on the San Benito side of the county-line, produced 25 to 30 flasks of quicksilver about 1942 from two separate operations conducted by Tom Akers and E. T. Haun. Ore came from a 70-foot shaft that followed a pipe, and only a few feet of drifting was done. Country rock around the shaft is basalt.

Tirado mine in sec. 18, T. 18 S., R. 12 E., M.D., and sec. 13, T. 18 S., R. 11 E., is owned by Ben and Paul Hilden of Hernandez. Cinnabar is found in silica-carbonate rock along shear zones in serpentine, and some production was made from open cuts in 1942.

---

[28] Bradley, W. W., Quicksilver resources of California: California Min. Bur. Bull. 78, p. 106, 1918.

Tirado and Shear mines in sec. 12, T. 18 S., R. 11 E., M.D., are owned by S. Tirado and William Shear of Hernandez. The occurrence is similar to that at the Tirado.

Valley View mine is in secs. 7 and 8, T. 15 S., R. 10 E., M.D., and sec. 12, T. 15 S., R. 9 E., 2 miles north of Llanada and is owned by Louis Schiochetti and George Valdez of Hollister. The mine was located in 1938, and was equipped with a 4- by 64-foot rotary furnace in 1940, but this was removed in 1943. A production of 319 flasks of quicksilver was made from 15,000 tons of ore. Geology and maps and sections of the 1,500 feet of workings are contained in the report by Yates and Hilpert [29].

Wonder mine is in sec. 31, T. 17 S., R. 12 E., M.D., 2 miles northwest of Llanada, and is owned by Paul Gonzales of King City. About 400 feet of underground workings have been driven, and some production was made in 1942. The ore is in crushed Franciscan sandstone.

Yturriarte mine in sec. 12, T. 15 S., R. 9 E., M.D., 2 miles northwest of Llanada, is owned by Mrs. Frank McCullough of Hollister. Production from 1940-44 amounted to 18 flasks of quicksilver. Cinnabar is found in a breccia zone in Franciscan sandstone and shale. The property was idle in 1945. Sketch maps of the 400 feet of workings are contained in the report by Yates and Hilpert.[30]

Stone Industry
(Crushed Rock, Sand, and Gravel)

Granite Rock Company of Watsonville operates a very large plant at Logan just inside the boundary line of San Benito County. Mrs. A. R. Wilson is president, A. J. Wilson is vice-president and general manager, John E. Porter is secretary and sales manager, Royal E. Fowle is engineer and production manager, and Frank Swearingen is superintendent.

Production capacity is 750 tons per hour, and facilities are provided for loading directly on railroad cars. A wide range of sizes of crushed granite rock suitable for the following uses is made: concrete pavements, structures, walks, floors, and pipe; railroad-ballast, asphaltic concrete, plant-mix surfacing, Virginia mix, parking-area surfaces, screenings, sewage-disposal plant filters, water-supply filters, chicken and turkey grits, penetration-asphalt macadam, armor coat, retreads, seal coats, drains, and rip-rap.

A granite crusher-run base is also sold for the following uses: bases for highways, runways, parking areas, hard-standing areas, warehouse and factory floors, driveways and walks. It has been successfully used as fill and base material on unstable or sandy soils in connection with railway and highway construction.

As details of the plant have been described in an illustrated article by Royal E. Fowle [31] they are not repeated here. The San Andreas fault has assisted in crushing the granite to such an extent that much less blasting is needed at this quarry than in the average quarry in granite. The faulting and other features of the geology have been described by Allen.[32]

---

[29] Op. cit., pp. 29-30.
[30] Op. cit., p. 35.
[31] Fowle, R. E., Operations of the Granite Rock Company quarry and plant at Logan, San Benito County: California Div. Mines Bull. 133, pp. 77-81, pls. 9-12, 1946.
[32] Allen, J. E., op. cit., pp. 72-73.

CONDENSER INSTALLATION AT THE NEW IDRIA QUICKSILVER MINING COMPANY, IDRIA, CALIFORNIA*

By Richard A. Crippen, Jr.**

ILLUSTRATIONS

During the war with Japan in the south Pacific islands, a number of new uses for mercury were developed. An electric dry cell using an oxide of mercury, unaffected by jungle dampness and much smaller and lighter than dry cells previously in use, was in great demand for "walkie-talkie" radios and a multitude of other types of electrical equipment. Other salts of mercury were used in treating leather and fabrics to resist the molds and rot which otherwise destroyed them quickly in jungle warfare.

At New Idria, the old methods of handling mercury from the condenser hoppers in hard rubber buckets were wasteful of both mercury and manpower. These considerations, plus the necessity of soon replacing the old corroded condenser pipes brought about an idea for a new, efficient, and economical installation, with features and arrangement new to the quicksilver mining industry. It was conceived by C. Hyde Lewis, superintendent, early in 1945; and after several months of consideration and study of the problems involved, final plans were drawn up and work started in May 1945.

The writer, employed at New Idria during the war, made the working drawings and directed construction of the condenser installation. It was completed in September 1945, but the ending of the war and the accompanying uncertainties caused the mine to shut down for 2 months. With resumption of operations in December the new condenser was put in service and with very minor changes has proved its worth over the past year. Savings in labor cost over the old method have been a large factor in the continued operation of the mine under the recent low price for mercury.

Designed to handle the product of two of the four rotary kilns, the condenser was built in the space formerly occupied by the two banks of condenser pipes and launder trays of the old system of kilns 1 and 2.

One sees first the large pan of the hoeing machine. It is about 15 feet in diameter, with four sets of cultivator disc blades on arms from a central shaft. These blades stir the drying mud on the water-heated pan, and the freed mercury runs toward the inner steel wall, the pan bottom being slightly dished. A pipe opening flush with the bottom of this lower part of the pan drains the mercury by gravity to the purifying and bottling apparatus nearby. A "Wemco" worm and gear and a reduction-geared 1-horsepower motor, set in the center opening of the pan, turn the disc arms at a fraction of 1 revolution per minute. The vertical shaft continues upward through the 3-foot-diameter center opening in the concrete settling tank just overhead, thus also operating the concentrating sweep arm in the tank.

On four heavy concrete piers, arranged tangentially, are four concrete columns supporting concrete beams under the tank. These columns

* Permission to publish this account was granted by Mr. Gordon Gould of the H. W. Gould Company, operators of the New Idria and other mines. The writer wishes to thank them and Mr. C. Hyde Lewis for their kindness and hospitality at the mine.

** Supervising geological draftsman, Division of Mines, San Francisco.

have a corner out from and extending slightly above the tank rim to support steel I-beams of the condenser-pipe framing above the tank. Four other smaller columns on the same piers also support steel I-beams over the tank.

Near the midpoint of the radius of the concrete tank bottom, at one side, is a steel hopper bolted to the bottom. It tapers to a 4-inch lever-operated valve just over the edge of the hoeing-machine pan. Opening the valve permits the accumulated mercury and mud to flush out onto the pan. The bottom of the concrete settling tank slopes from the outer wall and equally from the wall of the center opening, producing a flat V-shaped annular trough in which is the hole over the hopper. In diameter the tank is nearly 26 feet, with 3-foot walls on the outside.

Just over the tank is the steel I-beam and timber frame of the condenser-pipe assembly with the lower hopper returns projecting down into the water of the tank. Two central wide-flange steel I-beams, 9 by 24 inches, and two outer ones 6 by 12 inches, carry the near hundred tons of pipes and timber over the tank. The pipes are 16 inches inside diameter, 12 feet long, of centrifugally cast iron, in banks, two lengths in height connected at the top by 180-degree returns and at the bottom by the hopper returns. Four stands of pipe are omitted at the center of the square assembly for more equal cooling.

The foregoing description gives a general picture of the structure. Some of the details of construction and operation may be of interest.

There is no sand and gravel within many miles of Idria suitable for aggregate in concrete work; however, there are millions of tons of burnt ore in the dumps, and this material, principally sharp, hard shale fragments, long has been used as aggregate and as road metal. For the rather critical strength requirements of the reinforced concrete tank and columns, a properly balanced aggregate was necessary. By sieve analysis, certain proportions of the burnt ore of two different dumps were chosen and blended at the mixer. Power shovels loaded the trucks which carried sloping screens to eliminate the very coarse rock. Good concrete practice was followed with the addition of a cupful to a mix of a patented preparation used to waterproof the concrete and minimize shrinkage and cracking. At the time of the writer's visit in February 1947, 1½ years after installation, no cracking was visible.

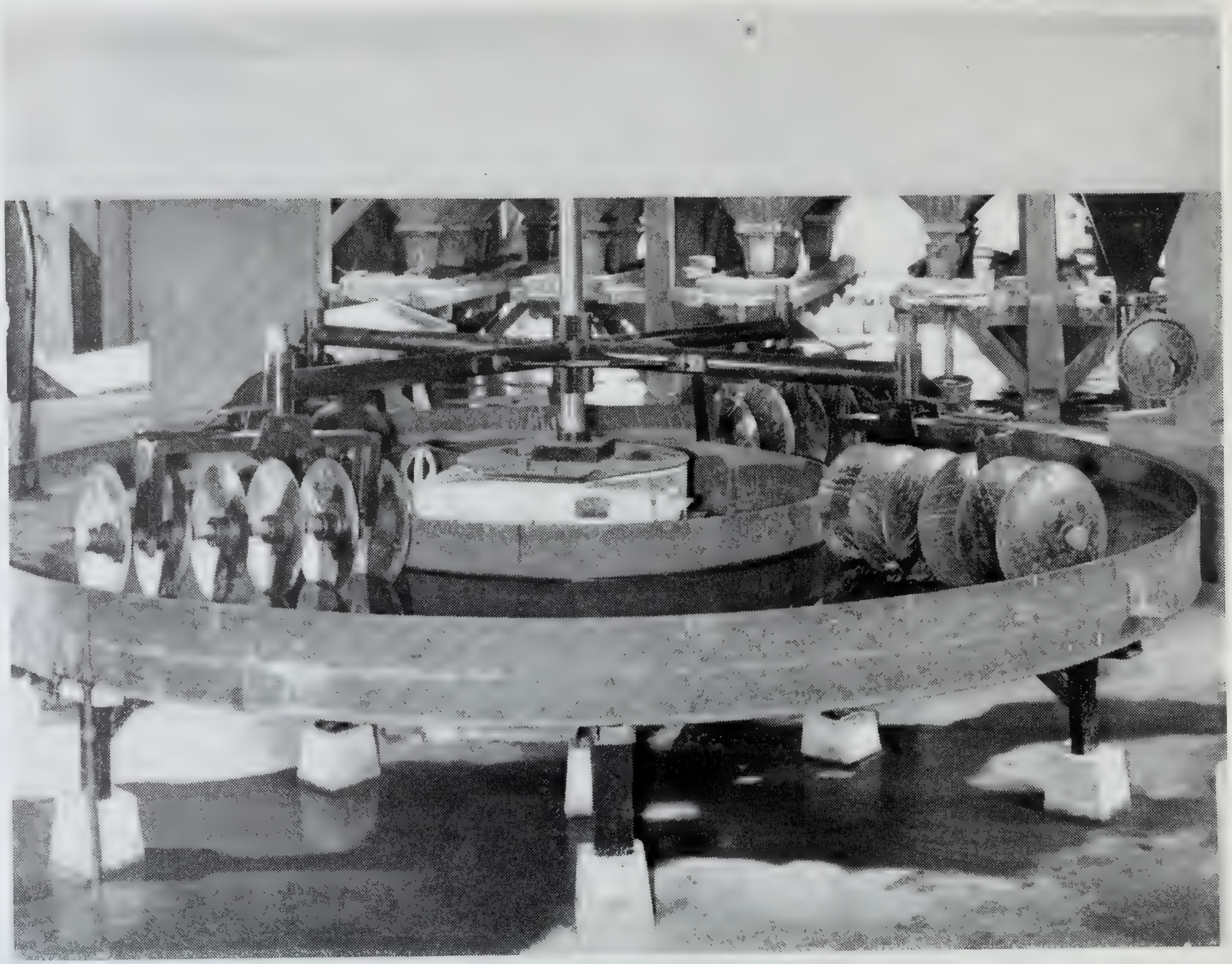
The hoeing-machine pan was fabricated in San Francisco in two halves which were welded together when installed. It is double bottomed, with water in the lower part heated by electric heat elements. The mud and mercury from the condenser form a mechanical mixture, the mercury in minute globules refusing to unite into the liquid, probably due to the globules acquiring an oily coating upon condensing. Dehydated lime mixed with the mud in the hoeing machine, perhaps combined with the drying heat and stirring, frees the mercury and it runs out in bright rivulets. The remaining mud, still carrying some mercury, is returned to the kiln for reburning.

Improvement in quicksilver-reduction practice at New Idria is shown by the constant reduction of the kiln-room payroll. Twenty or more men per shift were needed in the years before 1940. During the war five to ten men, and now two per shift, easily operate the entire reduction plant. The back-breaking lifting of the heavy mercury buckets is eliminated, and the condenser and hoeing table operate with but occasional attention; health hazards from inhalation or skin contact with the mercury vapor or metal are reduced to a safe minimum.

NEW IDRIA QUICKSILVER MINING COMPANY, 1945

Looking south toward bunkhouses, general store, cookhouse, "movies" and union hall, in foreground. Reduction plant and waste fumes stack beyond. Waste dump is from main haulage adit, 10 level.

Photo by courtesy H. W. Gould Company



HOEING MACHINE UNIT OF NEW QUICKSILVER CONDENSING INSTALLATION IN THE NEW IDRIA QUICKSILVER MINING COMPANY PLANT

Hopper and valve of settling tank at right. Buckets and launder trays of old condensing system for kilns 3 and 4 can be seen beyond.

Photo by courtesy of H. W. Gould Company

INFORMATION IN REGARD TO MINING CLAIMS ON THE PUBLIC DOMAIN *

The purpose of this circular is to furnish brief information pertinent to the location and purchase of mining claims under the United States mining laws.

1. *Initiation of rights to mineral land.*—Rights to mineral lands, owned by the United States, are initiated by prospecting for minerals thereon, and, upon the discovery of mineral, by locating the lands upon which such discovery has been made. A location is made by staking the corners of the claim, posting notice of location thereon (see 10), and complying with the state laws, regarding the recording of the location in the county recorder's office, discovery work, etc.

2. *State mining laws.*—As supplemental to the United States mining laws there are state statutes relative to location, manner of recording of mining claims, etc., in the state, which should also be observed in the location of mining claims. Information as to state laws can be obtained locally or from state officials.

3. *Lands subject to location and purchase.*—Vacant public surveyed or unsurveyed lands are open to prospecting, and upon discovery of mineral, to location and purchase, as are also lands in national forests in the public-land states (forest regulations must be observed), lands entered or patented under the stock raising homestead law (title to minerals only can be acquired), lands entered under other agricultural laws but not perfected, where prospecting can be done peaceably, and lands within the railroad grants for which patents have not been issued.

4. *Status of lands.*—Information as to whether any particular tract of land is shown by the records to be vacant and open to prospecting may be obtained from the register of the land district in which the tract is situated. Since location notices of mining claims are filed in the office of the county recorder, ordinarily no information regarding unpatented mining claims is obtainable from the district land office or the General Land Office unless application for patent has been filed.

5. *Minerals subject to location.*—Whatever is recognized as a mineral by the standard authorities, whether metallic or other substance, when found in public lands in quantity and quality sufficient to render the lands valuable on account thereof, is treated as coming within the purview of the mining laws. Deposits of coal, oil, gas, oil shale, sodium, phosphate, potash, and in Louisiana and New Mexico sulphur, belonging to the United States, can be acquired under the mineral leasing laws, and are not subject to location and purchase under the United States mining laws.

6. *Mining locations—Areas.*—Lode locations for minerals discovered in lode or vein formation may not exceed in length 1,500 feet along the vein and in width 300 feet on each side of the middle of the vein, the end lines of the location to be parallel to each other. Placer locations, which include all minerals not occurring in vein or lode formation, may be for areas of not more than 20 acres for each locator, no claim to exceed 160 acres made by not less than eight locators. Placer locations must conform to the public surveys wherever practicable.

---

* This paper is a reprint of Circular 1278 of the General Land Office, United States Department of the Interior.

7. *Who may make locations.*—Citizens of the United States, or those who have declared their intention to become such, including minors who have reached the age of discretion and corporations organized under the laws of any state. Agents may make locations for qualified locators.

8. *Number of locations.*—The United States mining laws do not limit the number of locations that can be made by an individual or association.

9. *Valid locations—Discovery after conveyance.*—A location is not valid until an actual discovery of mineral is made within the limits thereof. A placer location of more than 20 acres, made by two or more locators and conveyed to a less number before discovery is made, is valid to the extent of 20 acres only for each owner at date of discovery.

10. *Locations to be marked on ground—Notice.*—Except placer claims described by legal subdivision, all mining claims must be distinctly marked on the ground so that their boundaries may be readily traced, and all notices must contain the name or names of the locators, the date of location and such a description of the claim by reference to some natural object or permanent monument as will serve to identify the claim.

11. *Locations on streams and bodies of water.*—Beds of navigable waters are subject to the laws of the state in which they are situated and are not locatable under the United States mining laws. Title to the beds of meandered nonnavigable streams is in the riparian owner. The beds of unmeandered, nonnavigable streams are subject to location under the United States mining laws if they are unoccupied, as are also the beds of meandered nonnavigable streams when the abutting upland is unappropriated.

12. *Maintenance—Annual assessment work—Adverse claim—Jurisdiction.*—The right of possession to a valid mining claim is maintained by the expenditure annually of at least $100 in labor or improvements of a mining nature on the claim, the first annual assessment period commencing at 12 o'clock noon on the 1st day of July succeeding the date of location. Failure to perform the assessment work for any year will subject the claim to relocation, unless work for the benefit of the claim is resumed before a relocation is made. The determination of the question of the right of possession between rival or adverse claimants to the same mineral land is committed exclusively to the court. (See 18.) However, failure to perform the annual assessment work on a mining claim in Alaska works a forfeiture of the claim, and resumption of work on the claim will not prevent relocation.

13. *Expenditures on claim for patent purposes—Lode—Placer—Mill site.*—Five hundred dollars in labor or improvements of a mining nature, must be expended upon or for the benefit of each lode or placer claim, and compliance with the United States mining laws made otherwise, to entitle the claimant to prosecute patent proceedings therefor. Such expenditures must be completed prior to the expiration of the period during which notice of the patent proceedings is published. Patent expenditures on a mill site are not required, but it must be shown that the mill site is used or occupied for mining or milling purposes at the time an application for patent therefor is filed.

14. *Patent not necessary.*—One may develop, mine, and dispose of mineral in a valid mining location without obtaining a patent, but possessory right must be maintained by the performance of annual assessment work on the claim in order to prevent its relocation by another.

15. *Procedure to obtain patent to mining claims.*—The owner or owners of a valid mining location, or group of locations, on which not less than $500 has been expended on or for the benefit of each claim, may institute patent proceedings therefor in the district land office. Information as to patent procedure can be obtained from the register of the local land office or from the General Land Office. In general, a survey must be applied for unless the claim is a placer claim located by legal subdivisions, the application for survey to be made to the public survey office in the state wherein the claim is situated. Applications for patent are filed in the district land office. A notice of the application is required to be posted on the land prior to filing the application and to be published by the register after the application is filed.

16. *Blank forms.*—No set form of location notices nor of the papers filed in patent proceedings for mining claims is required and no blank forms are furnished by the General Land Office, or by the district land offices, for use in mineral cases. Forms containing essentials are printed by local private parties or concerns. The registers of the local land offices can usually advise you where such forms may be obtained.

17. *Common improvements.*—An improvement, made upon one of a group of contiguous claims (cornering is not contiguity) owned in common, may be applied to such claims of the group, in existence at the time the improvement is made, shown to be benefited thereby.

18. *Adverse claims.*—An adverse claim may be filed during the period of publication of notice of an application for patent (or within 8 months after the expiration of the publication period in Alaska), by one claiming a possessory right under another mining location to all or to some portion of the land applied for, and must show fully the nature, boundaries, and extent of the area in conflict, to be followed, within 30 days after filing (60 days in Alaska), by suit in a court of competent jurisdiction. If suit is filed, all proceedings on the application, except the filing of the affidavits of continuous posting and publication of the notice of the application, are stayed to await the outcome of the court proceedings.

19. *Coowners.*—A coowner not named in the application for patent can not assert his rights by filing an adverse claim, a protest being proper to cause his alleged rights to be considered when the case is adjudicated. If a coowner fails to do his proper proportion of annual assessment work on a claim, or fails to contribute his proportion of the cost thereof, the coowners who have caused the work to be done during any assessment period may, at the expiration of the assessment year, give such delinquent coowner personal notice in writing, or notice by publication in a newspaper published nearest the claim for at least once a week for 90 days, and if at the expiration of 90 days after such notice in writing, or 180 days after the first newspaper publication, such delinquent should fail to contribute his proportion of the expense required, his interest in

the claim becomes the property of his coowners who have made the expenditure.

20. *Lode in placer.*—If a placer mining applicant fails to state that there is a known lode within the boundaries of the claim, it is taken as a conclusive declaration that he has no right of possession thereto. If no such vein or lode be known the placer patent will convey all valuable mineral and other deposits within the boundaries of the claim. A known lode not included in an application for patent to the claim may be applied for even after issuance of patent to the placer mining claim. Where a placer mining claimant makes application for a placer containing within its boundaries a lode claim owned by him the lode must be surveyed, the lode being paid for on the basis of $5 per acre and the remaining portions of the placer at the rate of $2.50 per acre.

21. *The United States mining laws are applicable to the following states:* Alaska, Arizona, Arkansas, California, Colorado, Florida, Idaho, Louisiana, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming.

22. *National parks and monuments.*—With the exception of Mt. McKinley National Park in Alaska and Death Valley National Monument in California mining locations may not be made on lands in national parks and monuments after their establishment.

23. *Withdrawals.*—Withdrawals usually bar location under the mining laws, but withdrawals made under the act of June 25, 1910 (36 Stat. 847), as amended by the act of August 24, 1912 (37 Stat. 497), permit locations of the withdrawn lands containing metalliferous minerals. Lands withdrawn for water power purposes are not subject to location unless first restored under the provisions of section 24 of the Federal Water Power Act.

24. *Minerals in Indian lands.*—In general, the mineral deposits in Indian reservations are subject to leasing and are under the administration of the Office of Indian Affairs.

25. *Mineral land in agricultural entries—Protest—Contest.*—Where lands known to be valuable for minerals are embraced in an agricultural filing, other than a stock raising homestead filing, a mineral claimant may initiate a contest thereagainst by filing a protest sworn to and in duplicate, in the local land office, alleging sufficient facts, which, if proven, will establish the mineral character of the land, and warrant cancellation of the agricultural filing. The protest must be corroborated by one or more witnesses having knowledge of the facts alleged. In the case of stock raising homstead entries, a mineral claimant, whose location antedates the homestead filing, must protest such filing in order to protect his title to the surface of his mining claims.

26. *Cost of patent proceedings for mining claims.*—With the exception of the fixed charges, such as the fee for filing an application for patent, which is $10, the purchase price of lands in lode claims and millsites at $5 per acre, and $5 for each fractional part of an acre, and $2.50 per acre or fraction of an acre for placer lands, unless otherwise provided by law as to certain lands, no estimate can be furnished as to what it will cost to procure a patent. The cost of publication, survey, and abstract of title depends upon the services rendered and vary in each case.

FRED W. JOHNSON, *Commissioner.*

MINERAL PATENTS *

The development of the mineral resources of the public lands is an important part of the program of the Department of the Interior for conservation through wise use of our natural resources.

With a view to advising prospective applicants concerning the procedure for obtaining patent to a mining claim, the General Land Office presents this bulletin.

(Sgd) FRED W. JOHNSON
Commissioner,
General Land Office

October 1940.

Deposits of minerals, other than coal, oil, gas, oil shale, sodium, phosphate and potash (sulphur in Louisiana and New Mexico) in both surveyed and unsurveyed lands belonging to the United States are open to exploration and purchase under the mining laws of May 10, 1872. The lands in which the minerals are found are open to occupation and purchase by citizens of the United States or those who have declared their intentions to become citizens, under regulations prescribed by the Secretary of the Interior, and according to the local customs or rules of miners in the several mining districts, so far as they are applicable and not inconsistent with the laws of the United States. Certain minerals belonging to the United States (coal, oil, gas, oil shale, sodium, potash, phosphate, and in Louisiana and New Mexico, sulphur) may be acquired under what are known as the mineral leasing laws and are not subject to location and purchase under the mining laws. Information regarding the acquisition of any of these leasable minerals will be furnished upon request.

Under the provisions of the mining laws, the locator or owner of a valid mining location has the right to the exclusive possession for mining purposes of the land embraced in the location, and may continue to hold such possession so long as he performs labor or makes improvements of not less than $100 in value on or for the benefit of the claim each assessment year. Upon failure to comply with the assessment work requirement during any year, the claim is open to relocation at any time prior to the resumption of work by the owner, or his heirs, legal representatives or assigns. Thus, while a valid mining claim may be held and mined under the location title, that title may be lost by failure to perform the required annual assessment work, and for this reason it is desirable to obtain a patent for the claim, after which annual assessment work is no longer required. Before a patent can be obtained, not less than $500 must have been expended in labor or improvements in the development of the claim.

The procedure for obtaining patent to a mining claim is briefly set forth herein for the benefit of locators and owners of such claims.[1]

Applicants for mineral patents should proceed in the following order:

---

* This paper, which gives information relative to the procedure for obtaining patent to a mining claim, is reprinted from a mimeographed release (3657) by the General Land Office, United States Department of the Interior, October 1940.

[1] For information relating to prospecting, location of claims, and other work necessary before applying for patent, see Circular No. 1278, Information in Regard to Mining Claims on the Public Domain.

LODE CLAIMS

1. The claim must be surveyed. An application to have the survey made must be filed with the district cadastral engineer.

2. Formal notice of the application must be given by posting a copy of the plat of survey and a notice of application for patent on the claim.

3. A proper application for patent must be filed in the district land office supported by the following papers:

   (a) Copy of the field notes and plat of survey.
   (b) Proof of posting the plat and notice on the claim.
   (c) Abstract of title or proof of possessory right.
   (d) Proof of citizenship.
   (e) Payment of filing fee.
   (f) Publisher's agreement.
   (g) Notice for publication.
   (h) Notice for posting in district land office.

4. Final proceedings.

   (a) Proof of publication must be made.
   (b) Proof of continuous posting of plat and notice on claim during full 60-day period of publication must be made.
   (c) Affidavit that all fees and charges have been paid must be filed.
   (d) An application to purchase accompanied by tender of purchase price must be filed.
   (e) Diligence.

1. Survey

Claimant must apply to the district cadastral engineer for authority to survey the claim (list of titles, addresses and extent of districts of such engineers appended hereto). Form of application may be obtained from the district cadastral engineer. Deposit of a sum estimated by the district cadastral engineer as sufficient to cover cost of making plats and field notes must be made before survey will be authorized. Applicant will, by private contract, arrange with a United States mineral surveyor to make the survey. The applicant may obtain from the district cadastral engineer a list of United States mineral surveyors from which he can select one to employ to survey his claim.

2. Posting on Claim

After the survey, applicant will post a copy of the plat and a notice of intention to apply for a patent in a conspicuous place on the claim, or on one of a group of claims, where it can be readily seen by any interested party.

3. Application for Patent

The application must show that the applicant has the right of possession to the claim and applicant should state briefly but clearly the facts constituting the basis of his right to a patent, a full description of the vein or lode, whether ore has been extracted, and, if so, of what amount and value, and the precise place within the limits of each claim where the vein or lode is exposed.

In addition to the improvements mentioned in the field notes, it is proper that the claimant in his application for patent should describe in detail the shafts, cuts, tunnels, or other workings claimed as improvements, giving their dimensions, value, and the course and distance thereof to the nearest corner of the public surveys. This statement of the description and value of the improvements must be corroborated by the affidavits of two disinterested witnesses.

Application must be under oath and filed in duplicate and it and all supporting affidavits may be verified before any officer authorized to administer oaths within the land district where the claim is situated. Individual claimants must execute application, except that if claimant is absent from district, the application must be executed by an attorney in fact within the land district. Application by a corporation may be executed by its officers, or by an agent or attorney in fact who has been duly authorized.[2]

The application for patent will be filed in the district land office after plat and notice have been posted on the claim and must be supported by:

(a) Copy of the field notes and plat of survey.

(b) Proof of posting on claim.—The affidavit of two credible witnesses, not claimants or their attorneys in fact, giving date and place of posting, with copy of notice attached to the affidavit.

(c) Abstract of title.—The application for patent must be supported by a certified copy of each location notice and also by an abstract of title of each claim, brought down to a date reasonably near date of filing the application, and must be supplemented later to include date of filing of the application, and be certified to by the custodian of the records, or by an abstracter, who has been approved by the Commissioner of the General Land Office.

Proof of possessory title.—As to old claims, where the records have been lost or destroyed and where all controversy over the claims has long since ceased, applicant may furnish a certified copy of the statute of limitations, applicable to mining claims in the state, with his affidavit, corroborated by disinterested persons, showing the facts as to the origin and maintenance of his title, the area of the claim, the kind and extent of mining improvements, whether his title has been disputed in court proceedings or otherwise, with details, as well as any other matters known to him which bear upon his right of possession. A certificate, under seal, by the clerk of the court having jurisdiction, that no action involving right of possession to the claim is pending and that there has been no litigation in the court affecting the title to the claim for the time fixed by the statute of limitations in the state other than has been decided in favor of the applicant for patent, must be filed.

(d) Proof of citizenship.—Affidavits of citizenship may be executed either within or without the land district.

---

[2] Authority of attorney in fact.

(a) Attorney for individual shown by original or certified copy of power of attorney.

(b) Attorney for corporation shown by certified copy of resolution appointing or authorizing official to appoint, with original or certified copy of power of attorney in the latter case.

(1) Of a native-born citizen, by his affidavit of that fact.

(2) Of one who has declared his intention to become a citizen, or has been naturalized, his affidavit showing date, place and the court before which he declared his intention or from which his naturalization papers issued, and the number of certificate if known.

(3) Of an association, competent evidence as above of each member.

(4) Of a corporation, by a certified copy of its charter, or certificate of incorporation.

(e) Payment of filing fee.

(f) Publisher's agreement.

(g) Notice for publication.—At the expense of applicant in a newspaper designated by the Register; (a) in weekly paper, 9 consecutive insertions; (b) in daily paper, 61 consecutive insertions. In all cases publications must be in each issue published within a period of 61 days. Sample form containing essential data appended.

(h) Notice for posting in district land office.

4. Final Proceedings

(a) Proof of publication.—The sworn statement of the publisher that the notice was published for the stated period, giving the first and last dates of the publication.

(b) Proof of continuous posting.—The affidavit of the applicant or his duly authorized attorney in fact that the plat and notice remained conspicuously posted on the claim during the entire period of publication, giving dates.

(c) Proof of fees and charges paid.—Affidavit of claimant or attorney in fact that all fees and charges have been paid, itemizing them.

(d) Payment of purchase price.—The purchase price for lode claims of $5 for each acre or fraction thereof must be paid.

(e) Diligence.—Application must be completed within a reasonable time and failure to do so will result in its rejection.

The cost of obtaining a patent will vary in every case and includes the deposit with the district cadastral engineer to cover office work in connection with the survey, the amount agreed upon by the applicant and the mineral surveyor for surveying the claim, a filing fee of $10 to be paid to the Register when the application for patent is filed, the cost of furnishing an abstract of title of the claims applied for, the charge of the newspaper for publishing the notice of application, and the payment of the purchase price for the land to the Register when the proofs are completed and the application to purchase the claim is made. There will also be some incidental expense for payment of the officials administering oaths to the applicant and his witnesses and in many cases the applicant will employ an attorney to look after the patent proceedings whose fee must be considered in determining the cost of obtaining patent for a claim.

The applicant should consult the officials in the district land office concerning any matters about which he may not be fully informed.

PLACER CLAIMS

1. A mineral survey must be made of placer claims on unsurveyed lands or surveyed lands when the land cannot be described in terms of the public land survey.
2. Formal notice of the application must be given by posting a notice of intention to apply for a patent on the claim, and, if a mineral survey has been made, a copy of the plat must also be posted.
3. A proper application for patent must be filed in the district land office supported by the following papers:
   (a) Copy of the field notes and plat of survey.
   (b) Proof of posting the plat and notice on the claim.
   (c) Abstract of title or proof possessory right.
   (d) Proof of citizenship.
   (e) Payment of filing fee.
   (f) Publisher's agreement.
   (g) Notice for publication.
   (h) Notice for posting in district land office.
4. Final proceedings.
   (a) Proof of publication must be made.
   (b) Proof of continuous posting of plat and notice on claim during full 60-day period of publication must be made.
   (c) Affidavit that all fees and charges have been paid must be filed.
   (d) An application to purchase accompanied by tender of purchase price must be filed.
   (e) Diligence.

1. Survey

When applying for patent to placer claims on unsurveyed lands or on surveyed lands when the land applied for cannot be described in terms of the public land survey, it will be necessary to have a mineral survey made of the claims[3]. Claimant must apply to the district cadastral engineer for authority to survey the claim (list of titles, addresses and extent of districts of such engineers appended). Form of application may be obtained from the district cadastral engineer. Deposit of a sum estimated by the district cadastral engineer as sufficient to cover cost of making plats and field notes must be made before survey will be authorized. Applicant will, by private contract, arrange with a United States mineral surveyor to make the survey. The applicant may obtain from the district cadastral engineer a list of United States mineral surveyors from which he can select one to employ to survey his claim.

2. Posting on Claim

Applicant will post notice of intention to apply for a patent on the claim, and, if a mineral survey has been made, a copy of the plat must also be posted.

3. Application for Patent

The application must show that applicant has the right of possession to the claim and applicant should state briefly but clearly the facts constituting the basis of his right to a patent and such data as will support

[3] Where placer claims are upon surveyed lands and conform to legal subdivisions, no further survey or plat is required.

the claim that the land applied for is placer ground containing valuable deposits not in vein or lode formation and that title is sought, not to control water courses or to obtain valuable timber, but in good faith because of the mineral therein. This statement, of course, must depend upon the character of the deposit and the natural features of the ground, but the following details should be covered as fully as possible: If the claim is for a deposit of placer gold, there must be stated the yield per pan, or cubic yard, as shown by prospecting and development work, distance to bedrock, formation and extent of the deposit, and all other facts upon which he bases his allegation that the claim is valuable for its deposits of placer gold. If it is a building stone or deposit other than gold claimed under the placer laws, he must describe fully the amount, nature and extent of the deposits, stating the reasons he regards it as a valuable mineral claim. He will also be required to describe fully the natural features of the claim; streams, if any, must be fully described as to their course, amount of water carried and fall within the claim; and he must state kind and amount of timber and other vegetation thereon and adaptability to mining or other uses.

If the claim is all placer ground, that fact must be stated in the application and corroborated by accompanying proofs; if of mixed placer and lode, it should be so set out, with a description of all known lodes situated within the boundaries of the claim. A specific declaration must be furnished for each lode intended to be claimed. In all cases, whether the lode is claimed or excluded, it must be surveyed and marked upon the plat, the field notes and plat giving the area of the lode claim or claims and the area of the placer separately. All other known lodes are, by the silence of the applicant, excluded by law from all claim by him, of whatsoever nature, possessory or otherwise.

Although in cases of placers taken by special survey, the mineral surveyors are required to make full examination of all placer claims at the time of survey and file with the field notes a descriptive report, it is proper that the application for patent contain this information under oath. Since no examination and report by a mineral surveyor is available in cases of claims taken by legal subdivisions, the claimant, in his application, should describe in detail the shafts, cuts, tunnels, or other workings claimed as improvements, giving their dimensions, value, and the course and distance thereof to the nearest corner of the public surveys in addition to the data above required. This statement of the description and value of the improvements must be corroborated by the affidavits of two disinterested witnesses.

The application for patent must be under oath and filed in duplicate and it and all supporting affidavits may be verified before an officer authorized to administer oaths within the land district where the claim is situated. Individual claimants must execute the application, except that if claimant is absent from the district, the application must be executed by an attorney in fact within the land district. Application by a corporation may be executed by its officers, or by an agent or attorney in fact, who has been duly authorized[4].

---

[4] Authority of attorney in fact.

(a) Attorney for individual shown by original or certified copy of power of attorney.

(b) Attorney for corporation shown by certified copy of resolution appointing or authorizing official to appoint, with original or certified copy of power of attorney in the latter case.

The application must be filed in the district land office after notice of application for patent, together with a copy of the plat if a mineral survey has been made, has been posted on the claim, and must be supported by:

(a) Copy of the field notes and plat of survey.

(b) Proof of posting on claim.—The affidavits of two credible witnesses, not claimants or their attorneys in fact, giving data and place of posting, with copy of notice attached to the affidavit.

(c) Abstract of title.—The application for patent must be supported by a certified copy of each location notice and also by an abstract of title of each claim, brought down to a date reasonably near date of filing the application, and must be supplemented later to include date of filing of application, and be certified to by the custodian and the records or by an abstractor, who has been approved by the Commissioner of the General Land Office.

Proof of possessory title.—As to old claims, where the records have been lost or destroyed, and where all controversy over the claims has long since ceased, applicant may furnish a certified copy of the statute of limitations applicable to mining claims in the state, with his affidavit, corroborated by disinterested persons, showing the facts as to the origin and maintenance of his title, the area of the claim, the amount and extent of mining improvements, whether his title has been disputed in court proceedings or otherwise, with details, as well as any other matters known to him which bear upon his right of possession. A certificate, under seal, by the clerk of the court having jurisdiction, that no action involving right of possession to the claim is pending and that there has been no litigation in the court affecting the title to the claim for the time fixed by the statute of limitations in the state other than has been decided in favor of the applicant for patent, must be filed.

(d) Proof of citizenship.—Affidavits of citizenship may be executed either within or without the land district.

(1) Of a native-born citizen, by his affidavit of that fact.

(2) Of one who has declared his intention to become a citizen, or has been naturalized, his affidavit showing date, place, and the court before which he declared his intention, or from which his naturalization papers issued, and the number of certificate, if known. Of an association, competent evidence as above of each member.

(3) Of a corporation, by a certified copy of its charter, of certificate of incorporation.

(e) Payment of filing fee.

(f) Publisher's agreement.

(g) Notice for publication.—At the expense of applicant in a newspaper designated by the Register; (a) in weekly paper, 9 consecutive insertions; (b) in daily paper, 61 consecutive insertions. In all cases, publication must be in each issue published within a period of 61 days. Sample form containing essential data appended.

(h) Notice for posting in district land office.

4. Final Proceedings

(a) Proof of publication.—The sworn statement of the publisher that the notice was published for the stated period, giving the first and last dates of the publication.

(b) Proof of continuous posting.—The affidavit of the applicant or his duly authorized attorney in fact that the plat and notice remained continuously posted on the claim during the entire period of publication, giving dates.

(c) Proof of fees and charges paid.—Affidavit of claimant or attorney in fact that all fees and charges have been paid, itemizing them.

(d) Payment of purchase price.—The purchase price for placer claims of $2.50 for each acre or fraction thereof must be paid.

(e) Diligence.—Applications must be completed within a reasonable time and failure to do so will result in their rejection.

The cost of obtaining a patent will vary in every case and includes the deposit with the district cadastral engineer to cover office work in connection with the survey, the amount agreed upon by the applicant and the mineral surveyor for surveying the claim, a filing fee of $10 to be paid to the Register when the application for patent is filed, the cost of furnishing an abstract of title of the claims applied for, the charge of the newspaper for publishing the notice of application, and the payment of the purchase price for the land to the Register when the proofs are completed and the application to purchase the claim is made. There will also be some incidental expense for payment of the officials administering oaths to the applicant and his witnesses and in many cases the applicant will employ an attorney to look after the patent proceedings whose fee must be considered in determining the cost of obtaining patent for a claim.

The applicant should consult the officials in the district land office concerning any matters about which he may not be fully informed.

ADVERSE CLAIMS

Adverse claims must be filed within the 60-day period of publication. (In Alaska, eight months' additional time is allowed beyond the 60-day period). The claims must be verified by claimant or attorney in fact (with proof of authority) within the land district, must set forth the nature and extent of the conflict, and the interest of the adverse claimant with certified copy of location certificate. Abstract of title prepared by an authorized abstractor and other necessary papers must be filed. Unless the claim is described by legal subdivisions, a plat showing the extent and boundaries of the claim and the conflict must be filed.

Suit must be commenced in a court of competent jurisdiction to determine the right of possession, within 30 days (in Alaska within 60 days) from the date of filing of the adverse claim, and it must be diligently prosecuted to final judgment.

Upon the filing of an adverse claim and commencement of suit, all proceedings in the land office will be stayed until the controversy shall be settled or the adverse claim waived.

A copy of the judgment roll, certified by the clerk of court or his certificate that suit has been dismissed or withdrawn is required as proof of termination of suit.

SAMPLE FORM OF NOTICE FOR PUBLICATION

It is expected that these notices shall not be so abbreviated as to curtail the description essential to a perfect notice, and on the other hand that they shall not be of unnecessary length. The printed matter must be set solid without paragraphing or any display in the heading and shall

be set in the usual body type used in legal notices. If other type is used, no allowance will be made for additional space on that account. The number of solid lines only used in advertising by actual count will be allowed. All abbreviations and copy must be strictly followed. The following is a sample of advertisement set up in accordance with Government requirements and contains all the essential data necessary for publication:

M. A. No. 053715, U. S. Land Office, Los Angeles, California, February 15, 1940. Notice is hereby given that Mary L. Murray, whose address is 6920 Hollywood Blvd., Los Angeles, California, has made application for mineral patent to the Alexander, Two Pagans, Mary L. Sterling and Little Jim Lode Mining Claims, and Numbers One, Two, Three and Four Mill Sites, all under Mineral Survey No. 6043 A. & B., for lands described as follows, to-wit: Mining Claims: Commencing at Cor. No. 1 of the Sterling Lode Mining Claim, U. S. Mineral Survey No. 6043 A and B, whence the S. ¼ Cor. Sec. 28, T. 3 N., R. 14 W., S. B. M. bears S. 20° 44′ W., 778.0 ft.; thence N. 29° 36′ W. 1094.3 ft.; thence N. 1° 19′ E. 466.3 ft.; thence N. 60° 24′ E. 360.4 ft.; thence N. 11° 31′ W., 1100.0 ft.; thence N. 10° 41′ W., 1500.0 ft.; thence N. 60° 24′ E. 16.2 ft.; thence N. 25° 13′ W. 1047.9 ft.; thence N. 60° 24′ E. 525.0 ft.; thence S. 29° 25′ E. 1044.9 ft.; thence N. 60° 24′ E. 16.2 ft.; thence S. 10° 41′ E. 1500.0 ft.; thence S. 9° 51′ E. 1111.0 ft.; thence S. 29° 13′ E. 1494.4 ft.; thence S. 60° 24′ W. 1190.0 ft. to the place of beginning. Exclusive of conflict with Rice & McAnany No. 2 and Rice & McAnany No. 3 lodes of Survey No. 5490. Mill Sites: Commencing at Cor. No. 1 of Number Two Millsite, U. S. Mineral Survey No. 6043 A. & B., whence the S. ¼ Cor. Sec. 28, T. 3 N., R. 14 W., S. B. M. bears S. 23° 54′ W. 628.3 ft.; thence N. 33° 10′ E., 600 ft.; thence S. 56° 50′ E. 1452.0 ft.; thence S. 33° 10′ W. 342.3 ft.; thence N. 89° 53′ W., 472.5 ft.; thence N. 56° 50′ W., 1055.9 ft. to the place of beginning. Location notices are recorded as follows—all "Official Records" of Los Angeles County, California, except as otherwise noted: Alexander, Book 1318, p. 98; amended location, Book 7436, p. 94; Two Pagans, Book 1328, p. 80; amended location, Book 7458, p. 35; Mary L, Book 1328, p. 80; amended location, Book 8893, p. 390; Sterling, Book 49, p. 215 of Mining locations; amended location, Book 7446, p. 85; Little Jim, Book 1328, p. 79; amended location, Book 5174, p. 310; Mill Sites as follows: No. 1, Book 5807, p. 113; No. 2, Book 5731, p. 366; No. 3, Book 5731, p. 367; No. 4, Book 5609, p. 135. Conflicting claims in addition to those mentioned above: Red Cloud No. 2, Lode, Survey No. 5822, and Little Jim Lode, Survey No. 5866. No other adjoining claims. Paul B. Witmer, Register.

LIST OF DISTRICT, TITLES AND ADDRESSES OF CADASTRAL ENGINEERS

SUPERVISOR OF SURVEYS

Denver, Colorado

ALASKA

Juneau:
District Cadastral Engineer.

ARIZONA AND CALIFORNIA

Phoenix:
Office Cadastral Engineer.

Glendale:
District Cadastral Engineer.

COLORADO AND WYOMING

Denver:
District Cadastral Engineer.

Cheyenne:
Office Cadastral Engineer.

IDAHO, WASHINGTON AND MONTANA

Boise:
District Cadastral Engineer.

Olympia:
Office Cadastral Engineer.

Helena:
Office Cadastral Engineer.

NEW MEXICO

Santa Fe:
District Cadastral Engineer.

OREGON

Portland:
District Cadastral Engineer.

UTAH AND NEVADA

Salt Lake City:
District Cadastral Engineer.

Reno:
Office Cadastral Engineer.

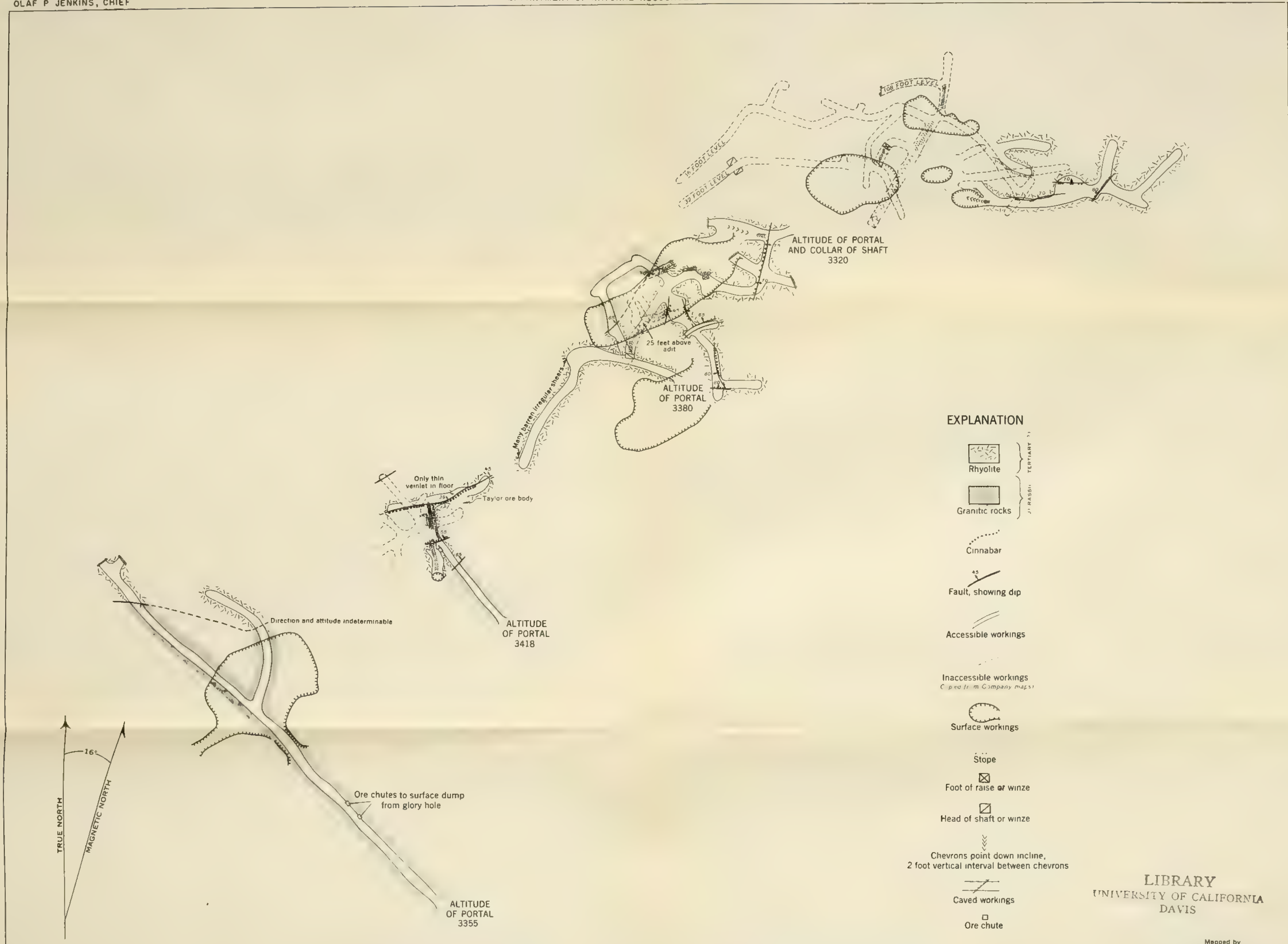
O

70558 3-47 2M

GEOLOGIC AND TOPOGRAPHIC MAP OF THE WALIBU QUICKSILVER MINE AREA
KERN COUNTY, CALIFORNIA

100 50 0 100 200 300 400 500 FEET

Contour interval 10 feet
Datum conforms with Company maps



GEOLOGIC MAP OF THE WALIBU QUICKSILVER MINE
KERN COUNTY, CALIFORNIA

40 0 40 80 120 FEET

January 1943

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

OLAF P. JENKINS, Chief

Vol. 43 | APRIL 1947 | No. 2

CALIFORNIA JOURNAL

OF

MINES AND GEOLOGY

printed in CALIFORNIA STATE PRINTING OFFICE
71637

STATE OF CALIFORNIA

EARL WARREN, Governor

DEPARTMENT OF NATURAL RESOURCES

WARREN T. HANNUM, Director

DIVISION OF MINES

OLAF P. JENKINS, Chief

Headquarters

Third Floor, Ferry Building, San Francisco 11

District Offices

State Building, 217 West First Street, Los Angeles 12
631 J Street, Sacramento 14
Box 445, Redding

The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles and Sacramento district offices.

In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology, and mining of California is given to the public by means of publications, mimeograph releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines consist of the quarterly periodical **California Journal of Mines and Geology**, issued in January, April, July, and October of each year, and a series of **Bulletins**. Mimeographed **Information Circulars** and **Announcements of New Publications** are also released periodically. A list of publications will be sent free upon request.

Organization and Personnel

(Effective July 1, 1947—99th Fiscal Year)

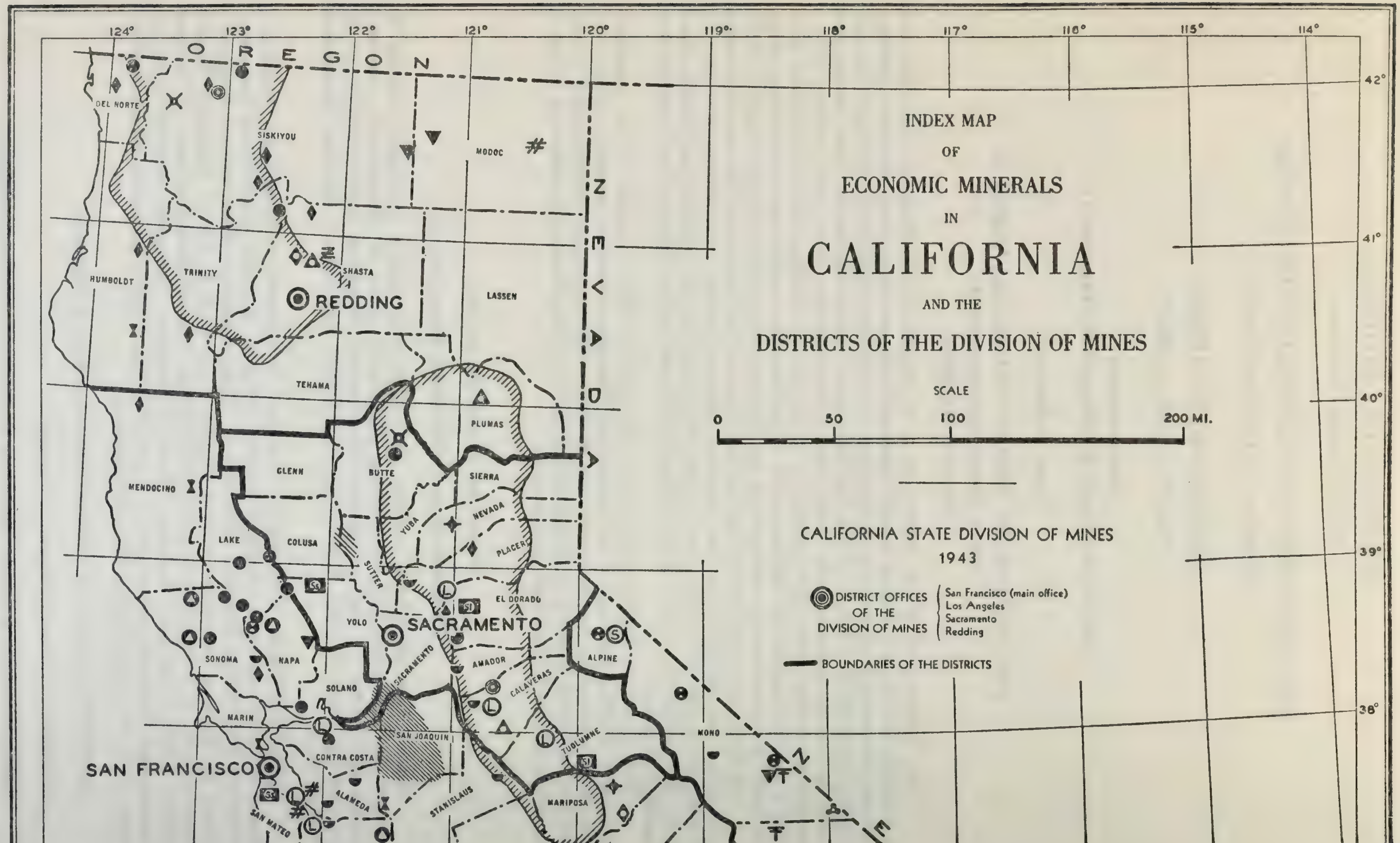
GEOLOGIC BRANCH: Parker D. Trask, Supervising Geologist; Lauren T. Wright, Associate Geologist. **Mineralogy Section:** Charles W. Chesterman, Assistant Geologist; George L. Gary, Mineral Technologist. **Drafting Section:** Richard A. Crippen Jr., Supervising Geological Draftsman; Edward J. Rhodes, Geological Draftsman.

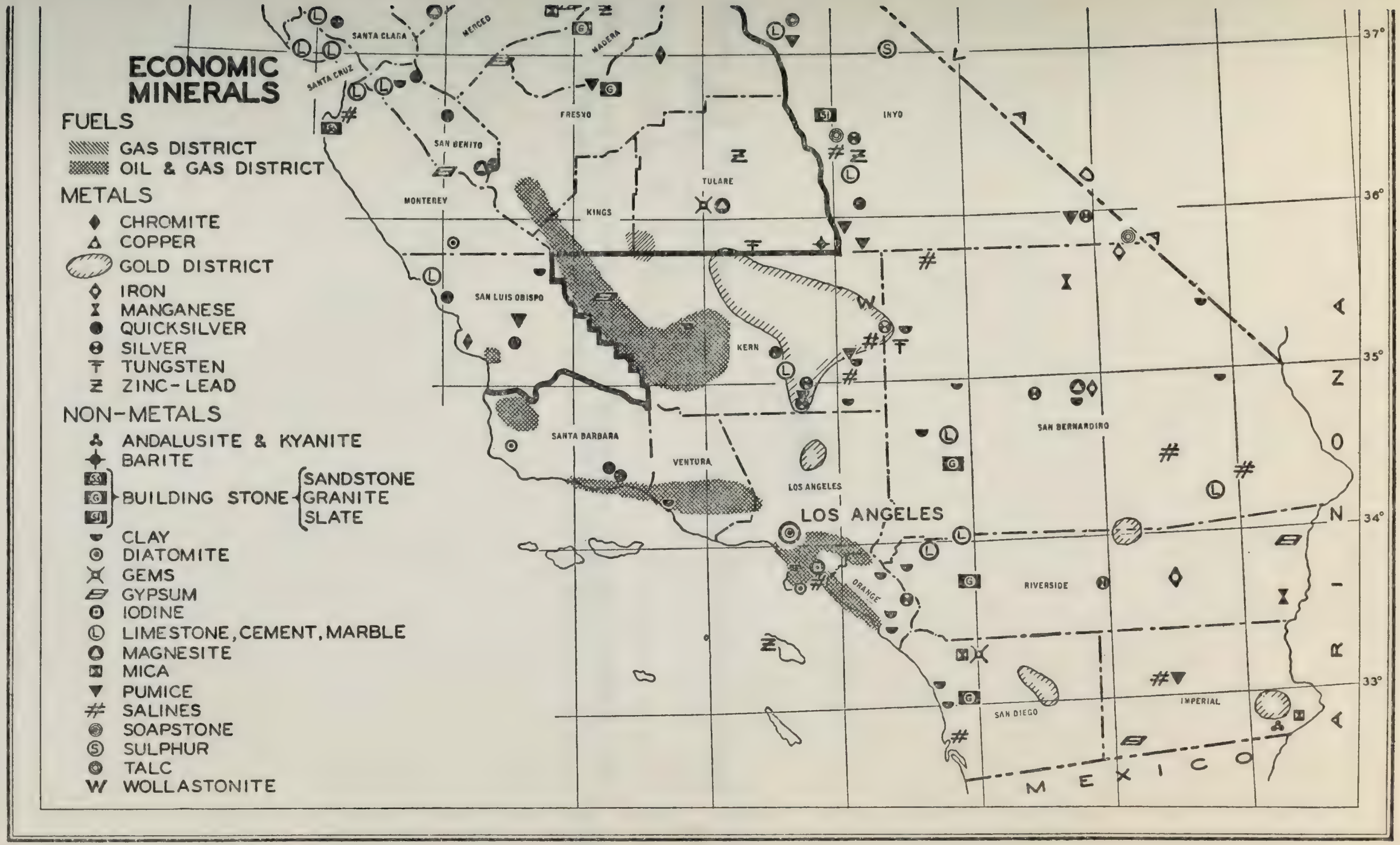
ENGINEERING BRANCH: Charles V. Averill, Supervising Engineer; James M. Little, Assistant Mining Engineer; John F. Bongard, Ore-Buyers' Inspector. **Minerals Economics Section:** Clarence R. King, Associate Metallurgical Engineer; Henry H. Symons, Assistant Mining Engineer; Fenelon F. Davis, Assistant Mining Engineer; W. B. Winston, Junior Mining Engineer. **Los Angeles District:** W. Burling Tucker, District Mining Engineer; Reid J. Sampson, Assistant Mining Engineer. **Sacramento District:** Clarence A. Logan, District Mining Engineer. **Redding District:** J. C. O'Brien, District Mining Engineer.

EXHIBITS: Henry H. Symons, Assistant Mining Engineer.

LIBRARY: Roy J. Nielsen, Librarian.

EDITORIAL SECTION: Elisabeth L. Egenhoff, Editorial Assistant.


INDEX MAP
OF
ECONOMIC MINERALS
IN
CALIFORNIA
AND THE
DISTRICTS OF THE DIVISION OF MINES
SCALE
0
50
100
200 MI.
CALIFORNIA STATE DIVISION OF MINES
1943
DISTRICT OFFICES OF THE DIVISION OF MINES
San Francisco (main office)
Los Angeles
Sacramento
Redding
BOUNDARIES OF THE DISTRICTS
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°
OREGON
NEVADA
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
MENDOCINO
YUBA
NEVADA
LAKE
COLUSA
PLACER
SUTTER
EL DORADO
YOLO
SACRAMENTO
SONOMA
NAPA
AMADOR
ALPINE
SOLANO
CALAVERAS
MARIN
SAN JOAQUIN
MONO
TUOLUMNE
SAN FRANCISCO
CONTRA COSTA
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO


ECONOMIC MINERALS
FUELS
GAS DISTRICT
OIL & GAS DISTRICT
METALS
CHROMITE
COPPER
GOLD DISTRICT
IRON
MANGANESE
QUICKSILVER
SILVER
TUNGSTEN
ZINC-LEAD
NON-METALS
ANDALUSITE & KYANITE
BARITE
BUILDING STONE
SANDSTONE
GRANITE
SLATE
CLAY
DIATOMITE
GEMS
GYPSUM
IODINE
LIMESTONE, CEMENT, MARBLE
MAGNESITE
MICA
PUMICE
SALINES
SOAPSTONE
SULPHUR
TALC
WOLLASTONITE
SANTA CLARA
SANTA CRUZ
MERCED
MADERA
FRESNO
SAN BENITO
MONTEREY
KINGS
TULARE
INYO
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
NEVADA
ARIZONA
MEXICO
37°
36°
35°
34°
33°

CONTENTS

MINES AND MINERAL RESOURCES OF STANISLAUS COUNTY, CALIFORNIA

By Abbott Charles *

OUTLINE OF REPORT

ILLUSTRATIONS

GEOGRAPHY

Stanislaus County is located at the northern end of the San Joaquin Valley, approximately in the center of California. It is bounded on the west by Santa Clara County, on the north by San Joaquin County, on the south by Merced County, and on the east by Calaveras and Tuolumne Counties. The land area of 1,506 square miles is populated by 74,866 people (1940 census). The population is estimated to have increased 51 percent from 1940 to 1946. The greater portion of the acreage is arable, accounting for a total agricultural and stock production of $77,339,239, in 1945. Of the land area 71.5 percent is in farms, putting this county in ninth place in richness of agricultural production in the United States. The yearly average rainfall for a 50-year period amounts to 12 inches. The wet season extends from October through March.

The eastern half of Stanislaus County is cut by the drainages of the Stanislaus and the Tuolumne Rivers, which flow westward. The San Joaquin River, flowing in a northwesterly direction, receives water from the other two drainages. These rivers supply the major part of the irrigation water for the county. Wells with an average depth of 215 feet are used to augment the water supply and to control the ground-water level.

Many good oil-surfaced roads traverse Stanislaus County. The unsurfaced dirt roads are kept in good condition during the dry season. Truck and scheduled bus lines serve the county. United Air Lines has

* Assistant mining engineer, California State Division of Mines. Manuscript submitted for publication March, 1947.

scheduled daily stops at Modesto. Rail facilities are supplied in this county by two Southern Pacific main lines, the "west side" line which runs from Tracy through Patterson and Newman, and the "east side" line which runs from Manteca through Modesto and Turlock; and a branch line that runs from Stockton through Oakdale and Waterford, ending at Montpelier. The Atchison, Topeka & Santa Fe Railway Company has a mainline track that runs through Riverbank, Hughson, and Denair, and has a branch line from Riverbank to Oakdale. The Tidewater Southern Railway Company has a line from Stockton, San Joaquin County, to Hilmar, Merced County, and Turlock, Stanislaus County. The Modesto and Empire Traction Company has a rail line from Modesto to Empire, where it connects with the Santa Fe system. The Sierra Railroad Company has a line from Oakdale to Tuolumne, Tuolumne County. At Oakdale this line connects with either the Santa Fe or the Southern Pacific systems.

The Modesto and Turlock Irrigation Districts furnish electrical power to their districts. The remaining portions of the county are serviced by the Pacific Gas and Electric Company.

Natural gas is supplied by the Pacific Gas and Electric Company to El Soyo (near Vernalis), Patterson, and Newman, and to Turlock, Keyes, Modesto, Riverbank, and Oakdale areas. Thomas E. Cooper supplies gas to 25 or 30 customers in Waterford, and the Osterburg Bros. supply about 100 customers half-way between Oakdale and Hughson.

GEOLOGY

The major portion of Stanislaus County is covered by the recent sediments of the San Joaquin Valley. The Diablo Range, a part of the Coast Ranges, forms the western boundary of the northern half of the San Joaquin Valley. Eocene and Miocene sediments are exposed about 6 miles west of Patterson and Newman, and the Jurassic-Franciscan group comprises the summit of the Diablo Range, the western boundary of the county. The Franciscan formation is composed of many varieties of sedimentary, igneous, and metamorphic rocks. The sediments include arkose sandstone, argillaceous shale, chert, siliceous shale, some conglomerate, and metamorphosed arenaceous and argillaceous materials. Igneous occurrences are principally basic, but some acidic porphyrites are found. In general, the intrusives have been altered to serpentine. The Franciscan formation is differentiated from the overlying Cretaceous strata mainly by its intense alteration. Lower Cretaceous sediments of the Shasta formation have been mapped by N. L. Taliaferro [1] in the southwestern portion of the county.

In most of this area the Panoche formation (Upper Cretaceous) rests unconformably upon the Franciscan complex. The Upper Cretaceous marine sediments of the Pacheco and Asuncion groups are composed mainly of gray and black clay-shales, often with lenses of shaly limestone, sandstone, and conglomerate. N. L. Taliaferro [2] states, "In northwestern

---

[1] Taliaferro, N. L., Geologic history and structure of the central Coast Ranges of California; California Div. Mines Bull. 118 pl. 1, 1943.
See also: Jenkins, Olaf P., Geologic map of California, scale 1:500,000, California Div. Mines, 1938. Anderson, R., and Pack, R. W., Geology and oil resources of the west border of the San Joaquin Valley north of Coalinga, California: U. S. Geol. Survey Bull. 603, 220 pp., 1915.

[2] Op. cit., p. 133.

Stanislaus County, west of Ingram Creek, the Mount Oso anticline causes a local thinning in the Panoche sandstones but not in the Moreno shales. This appears to have been another irregularity in the Upper Cretaceous sea. The buttressing effect of the Cretaceous Mount Oso anticline had a pronounced influence on the structures formed in the late Tertiary."

The Tejon formation of upper Eocene age is exposed from west of Patterson to the south beyond the county line. The Tejon is composed of fine-grained gray clayey sandstone with interstratified beds of fine-grained light-brown shale and gray clay. Layers of coal occur in the lower portion of these marine sediments. Upper Miocene marine sediments of the San Pablo formation can be traced along the base of the Diablo Range. The Kreyenhagen shale (upper Eocene) overlies the Tejon formation west of Crows Landing and extends southward to the county line.

Foothills of the Sierra Nevada expose upper Miocene sediments as far west as Denair, Waterford, and Valley Home. These are non-marine sediments of the Mehrten formation including sandstone, laminated siltstone, conglomerate, and andesitic breccia and tuff. The Valley Springs formation that underlies the Mehrten is composed principally of fragmental and glassy products from Miocene rhyolites. The Valley Springs formation extends the length of the eastern flank of Stanislaus County. Jurassic porphyrites closely follow the eastern edge of the county for most of its length. This porphyrite is an altered lava with the composition of andesite. In the Knights Ferry area, the Ione formation (upper Eocene) is locally exposed. Although the Ione group is exposed over a small area here, it is important economically owing to its clay and ochre content. A "tongue" of Upper Jurassic Mariposa formation extends from the southeast corner of the county to La Grange. The strata are mainly clay-slate with local sandy conglomerates and tuffs. Upper Eocene sediments composed mainly of light-colored tuffaceous beds exposed from Cooperstown south to the county line are no longer considered part of the Ione formation in view of the study by Allen.[3]

MINERAL RESOURCES

Gold has been the chief mineral product of Stanislaus County. Miscellaneous stone products hold second place in dollar value produced. The accompanying table gives the total recorded mineral production of Stanislaus County from 1880 through 1945.

Clay, chromite, coal, copper, gold, lead, magnesite, manganese, miscellaneous stone products, natural gas, (yellow) ochre, platinum and associated metals, silica, and silver comprise the real and potential natural resources of this county.

---

[3] Allen, V. T., The Ione formation of California: Univ. California, Dept. Geol. Sci. Bull., vol. 18, pp. 347-448, pls. 24-37, 1929.
See also: Turner, H. W., and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Sonora folio (no. 41), 1897. Piper, A. M., Gale, H. S., et al., Geology and groundwater hydrology of the Mokelumne area, California: U. S. Geol. Survey Water-Supply Paper 780, pp. 1-89, pl. 1, 1939.

Mineral production of

Year	Gold, value	Silver, value	Brick		Magnesite		Manganese	
			M	Value	Tons	Value	Tons	Value
1880	$73,271							
1881	63,000	$31,000						
1882	80,000	15,000						
1883	40,000	5,000						
1884	40,000	5,000						
1885	18,660							
1886	47,175							
1887	53,297							
1888	75,000							
1889	20,410							
1890	5,335							
1891	3,000							
1892	14,191							
1893	150							
1894	26,369							
1895	26,482							
1896	16,635							
1897	37,392							
1898	19,400							
1899	10,000							
1900	[1]21,212							
1901	[1]15,700				100	$600		
1902								
1903	[1]52,869	256						
1904	[1]50,000	265						
1905	[1]50,000	240						
1906	[3]	[3]						
1907	3,364	28						
1908	[2]	[2]	750	$7,000				
1909	[2]	[2]	5,000	50,000				
1910	[1]214,187	[1]604	1,500	8,000				
1911	[4]307,538	[4]1,131	850	5,950				
1912	[1]226,163	[1]1,974	250	2,000				
1913	[5]253,166	[2]671	300	2,400				
1914	[2]	[2]	250	2,500				
1915	[3]	[3]						
1916	[3]	[3]	[3]				160	$2,400
1917	[3]	[3]			3,196	44,350	775	26,925
1918	14,196	592			2,024	18,038	5,753	222,422
1919	[3]	[3]			2,031	20,831	8,921	374,584
1920	142,467	775			4,064	39,435	893	12,973
1921	18,439	136			3,378	33,158	[3]	
1922	[3]	[3]			2,400	35,475	[3]	[3]
1923	174,814	833						
1924	190,019	773					[3]	
1925	171,742	694					[3]	
1926	127,398	411					[3]	
1927	120,238	345					[3]	
1928	195,683	556			[3]			
1929	128,872	344			[3]		[3]	
1930	109,134	208			[3]			
1931	154,443	223			[3]			
1932	152,865	194			[3]			
1933	148,204	241			[3]			
1934	239,158	544			[3]			
1935	293,129	765			[3]			
1936	289,975	766			[3]			
1937	603,645	1,470			[3]			
1938	453,250	861			[3]			
1939	762,685	1,187			[3]			
1940	1,276,240	1,847			[3]		[3]	
1941	891,520	1,646			[3]		[3]	
1942	972,825	1,809			[3]		[3]	
1943	261,660	367			[3]		[3]	
1944	177,310	128			[3]		5,711	213,293
1945	264,040	366						
Totals	$10,197,917	$79,250	$8,900	$77,850	17,193	$191,887	22,213	$852,597

[1] Includes Merced County.
[2] See Merced County.
[3] See under 'Unapportioned.'
[4] Includes Merced County production; also dredge yield of Shasta and Trinity Counties.

Stanislaus County, 1880-1945

Mineral paint		Miscellaneous stone, value	Miscellaneous and unapportioned		
Tons	Value		Amount	Value	Substance
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	Quicksilver.[6]
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
---------	---------	---------	---------	---------	
105	$2,310	---------	---------	---------	
375	2,800	---------	20 flasks	$800	Quicksilver.
17	1,800	---------	---------	---------	
152	1,825	---------	---------	---------	
283	2,898	---------	---------	---------	
204	1,769	---------	---------	---------	
192	193	---------	---------	---------	
200	375	---------	79,330 lbs.	12,494	Copper.
200	350	---------	162,400 lbs.	18,676	Copper.
1,370	2,400	---------	116,000 lbs.	15,080	Copper.
200	1,600	---------	7,300 lbs. ---------	931 20	Copper. Platinum.
375	2,125	---------	---------	---------	
250	1,720	---------	---------	---------	
250	1,720	---------	---------	---------	
285	2,000	74,000	---------	---------	
285	2,225	225	---------	82,317	Unapportioned, 1900-1909.
40	270	---------	---------	---------	
96	600	---------	---------	---------	
100	600	63,572	---------	---------	
255	1,530	14,482	---------	---------	
52	286	3,096	---------	---------	
[3]	---------	2,250	---------	189,521	Gold, mineral paint, silver, platinum, quicksilver.
507	2,200	17,784	---------	230,638	Chromite, brick, gold, platinum, quicksilver, silver.
[3]	---------	6,240	1,438 tons ---------	29,240 183,167	Chromite. Gold, mineral paint, platinum, silver.
498	3,088	38,764	1,352 tons ---------	56,505 308	Chromite. Other minerals.
[3]	---------	28,922	---------	[1]165,989	Gold, mineral paint, platinum, silver.
669	7,062	181,262	---------	1,043	Platinum and quicksilver.
[3]	---------	180,697	---------	3,777	Manganese, mineral paint, platinum, quicksilver.
[3]	[3]	299,962	---------	116,730	Gold, manganese ore, mineral paint, platinum, silver.
1,023	10,745	231,965	---------	27,158	Magnesite, manganese ore, platinum.
[3]	---------	118,050	---------	30,296	Magnesite, manganese ore, mineral paint, platinum.
[3]	---------	221,256	---------	21,774	Magnesite, manganese ore, mineral paint, platinum.
[3]	---------	259,806	---------	12,957	Magnesite, mineral paint, platinum.
---------	---------	---------	---------	12,700	Magnesite, mineral paint, platinum.
[3]	---------	238,067	---------	37,852	Magnesite, mineral paint, platinum.
[3]	---------	233,325	---------	25,694	Clay (pottery), magnesite, manganese, mineral paint, platinum.
---------	---------	180,379	165 lbs. ---------	8 41,959	Lead. Clay (pottery), magnesite.
---------	---------	87,596	---------	35,019	Clay (pottery), magnesite, platinum.
---------	---------	55,595	607 lbs.	18	Lead.
---------	---------	40,888	---------	109,514	Clay (pottery), magnesite, platinum.
---------	---------	63,337	---------	115,133	Clay (pottery), magnesite, platinum.
---------	---------	111,912	---------	179,850	Pottery clay and magnesite.
---------	---------	177,015	---------	223,858	Pottery clay, magnesite, platinum.
---------	---------	57,147	---------	277,768	Other minerals.
---------	---------	290,036	---------	101,376	Pottery clay, magnesite, platinum.
---------	---------	134,582	---------	171,582	Pottery clay, magnesite, platinum.
---------	---------	61,306	---------	218,812	Pottery clay, magnesite, manganese ore, platinum.
---------	---------	148,644	---------	284,122	Pottery clay, magnesite, manganese ore, natural gas, platinum.
[3]	---------	222,241	---------	278,487	Pottery clay, mangesite, manganese ore, mineral paint, quicksilver, platinum, natural gas.
[3]	---------	397,616	---------	452,843	Pottery clay, gems (quartz), magnesite, manganese ore, mineral paint, natural gas, platinum, silica (quartz).
---------	---------	97,931	---------	56,714	Pottery clay, magnesite, natural gas.
---------	---------	112,932	---------	29,389	Manganese ore, natural gas, platinum.
7,983	$54,491	$4,452,882	---------	$3,852,119	

[5] Includes dredge production of Merced and Siskiyou Counties.

[6] There was a small production of quicksilver in the seventies and between 1884-1888, but no definite record of amounts.

Barium Products

Barium Products Limited[4] located in Modesto, is a wholly-owned subsidiary of Westvaco Chlorine Products Corporation. In 1925, Barium Products Limited purchased the Modesto plant of D-V-O Products Incorporated. This plant with a revised flow sheet utilizes barite, soda ash, acids, and carbonaceous material for the production of various barium chemicals. These are all produced by the treatment of barium carbonate made from "black ash" (crude barium sulphide) and soda ash. The "black ash" is produced in a rotary kiln from barite and carbon. The principal chemical products are barium carbonate, barium hydroxide, barium peroxide, hydrogen peroxide, refined barium sulfate (blanc fixe), and sodium sulfide.

Chromite

The discovery and first production of chromite from Stanislaus County were in 1916. The chromite occurs in the Franciscan formation in two types of deposits: (1) Lenses of hard, massive black ore containing little or no serpentine and having a well-defined contact with the surrounding serpentine; and (2) Deposits of gray ore mixed with serpentine and grading into it.[5]

With the advent of the first World War, an added demand was created for chromium. This stimulation led to the development of the following properties:

Adobe Canyon group (formerly known as the *Gray Fox claim* and the *Mountain View mine)*. These properties are located in secs. 14, 15, and 22, T. 6 S., R. 5 E., M.D., on the northeast slopes of Adobe Canyon near Del Puerto Creek. McGuire, Holbrook, & Springer shipped 500 tons of 40-percent chromic oxide prior to 1918 from several open cuts. The largest working was 30 feet deep and 100 feet long. The Chrome Concentrating Company acquired this property in 1917 and built a small mill to treat the disseminated ore. A tram line a quarter of a mile long was built from the mine to the mill. This company produced 260 tons of concentrates before suspending operations.

The ore body has a central core of high-grade chromite surrounded by a larger body of disseminated ore in serpentine. An estimated 350 tons of 10-percent ore remains in the upper glory hole at the present time. Southeast of this property 700 feet, a smaller deposit was found but was not developed. In this prospect the ore lies in flat sheets.

Black Bart group is in sec. 16, T. 6 S., R. 5 E., M.D., on the north side of Hideout Canyon, 2 miles northwest of the Adobe Canyon road. Ore was exposed continuously in a drift for 70 feet. A winze was sunk developing an estimated 1,200 tons of ore between the bottom of the shaft and the surface. An additional 1,000 tons of possible ore is estimated below the bottom level. The ore varies between 18 inches and 2 feet in width. Hand-picked ore runs 33.8 percent Cr_2O_3 and has a chromium-iron ratio of 2.28. The ore body has not shown any tendency to diminish in size with depth.

A smaller property immediately east of the above working has been opened by means of a shallow winze, but has not been fully developed.

---

[4] Williams, W. N., Barite in abundance: Chem. Met. Eng. vol. 42, no. 8, August, 1935.

[5] Bradley, W. W., et al., Manganese and chromium in California: California Min. Bur. Bull. 76, pp. 203-205, 1918.

Black Bear chrome mine is in sec. 22, T. 6 S., R. 5 E., M.D., on the north slope of Peachtree Canyon 1 mile east of the junction of Peachtree and Del Puerto Creeks. The ore body lies in a shear zone and has an average width of 18 inches in the stoped areas. A drift put in below these stopes was completely barren.

Chrome Camp mine is in the Stanislaus County Prison Reservation in sec. 14, T. 6 S., R. 5 E., M.D., half a mile north of Del Puerto Canyon road and 2 miles northeast of the junction between Del Puerto and Adobe Creeks. This deposit was exploited by the use of open cuts, the largest of which was 15 feet deep. From this cut 500 tons of 43-percent chrome ore was shipped. At the present time, almost no ore is visible in the workings.

Grummett mine is a prospect in sec. 6, T. 5 S., R. 6 E., M.D., 12 miles west of Westley, which shipped 100 tons of chromite in 1918. No ore has been produced since that time. This was an open-cut operation.

Lucky Girl mine, in sec. 22, T. 6 S., R. 5 E., M.D., is on the north side of Peachtree Canyon 3,400 feet east of its junction with Del Puerto Creek. This property adjoins the Black Bear chrome mine. Several small open cuts and adits produced 150 tons of 42-percent chrome ore from a distance of 70 feet along the vein. A lower adit was driven 75 feet along this fissure at a later date, developing only one small pod of massive chromite.

No. 5 group was operated to November 1918 by the Mineral Products Company and consists of five deposits immediately north of the Adobe Canyon group, on the north bank of Del Puerto Creek. The largest working in this group is in an outcrop exposed for almost 250 feet. The deposit was mined partly by open cut and partly by adit and flat stopes. In aggregate, about 800 tons of shipping ore were produced. Below this high-grade ore a disseminated ore zone was developed. This ore has an average grade of 15 percent chromic oxide, a thickness varying from 2 to 5 feet, and is over 300 feet in length. The ore was treated by the Chrome Concentrating Company, producing 270 tons of 51-percent Cr_2O_3 concentrates. During the idle years since 1918, the block carrying the mineralization caved and slid into the canyon. In 1940 West Coast Chrome tried, unsuccessfully, to find an extension of this ore with a bulldozer.

An additional 250 tons of mill-grade ore was taken from two open cuts 600 feet south of the main working. Five hundred tons of 40-percent ore was gained from several open pits and adits on the opposite side of the canyon. No appreciable reserves are credited to this group.

With the ending of hostilities in 1918, chromite mining in Stanislaus County was brought to an end. The industry remained dormant until the second World War period when the West Coast Chrome Company acquired the rights to most of the original workings. A small mill was installed, and 152 tons of chromite were shipped from Del Puerto district in 1940. Since that time no chromite has been produced in Stanislaus County. It has been estimated that a reserve of 1,850 tons[6] of 10- to 15-percent Cr_2O_3 ore remains in Del Puerto area.

Clay

Pottery-grade clay was produced from the Knights Ferry district in the NE ¼ sec. 29, T. 1 S., R. 12 E., M. D., by V. J. Winkler in 1933,

[6] Hawkes, E. H. Jr., Wells, F. G., and Wheeler, D. P. Jr., Chromite and quicksilver deposits of the Del Puerto area, Stanislaus County, California: U. S. Geol. Survey Bull. 936-D, pp. 96-104, 1942.

1934, and 1936. This deposit is the only one known to have produced clay of pottery quality in Stanislaus County. The plastic clays of this district are from the Ione formation.[7]

Deposits of low-grade clay suitable for the manufacture of common brick are found near Modesto, Grayson, Newman, and Patterson. None of these deposits have been worked in recent years, and no brickyard is in operation in the county.

Coal

Small veins of coal have been reported at the foot of the Diablo Range. They are located on Ensalada Creek, sec. 12, T. 6 S., R. 7 E., M. D.; Ingram Canyon, sec. 12, T. 5 S., R. 6 E., M. D.; and on Hoges Ranch, about 13 miles northwest of Newman. None of these deposits have been developed.

Copper

Copper Mountain and *Wild West* claims were located on Copper Mountain in or about the year 1870, and a tunnel 90 feet in length was driven thereon. It is said that the ore was low grade and that no definite ledge was struck. The claims were soon abandoned and have remained inactive.

Diatomaceous Earth

Simon Newman Company of Newman owns a large deposit of salt-water diatomite in secs. 1, 12, and 13, T. 7 S., R. 7 E., M. D., and sec. 36, T. 6 S., R. 7 E., M. D. Otis Allen Causey, Ceres, California, is the present lessee. At this time the property is not in operation. The diatomite is of good grade and the deposit extensive.

Gold

No lode-gold property has been definitely established in Stanislaus County.

Placer mining has been active in the Stanislaus River channels above Oakdale and in the Tuolumne River channels above Waterford. The Intervolcanic Cataract channel, described by Lindgren,[8] is cut by the Stanislaus River above Knights Ferry and may be the major source of the gold in the Knights Ferry area.

C. and E. Dredging Company operated a dragline excavator with a 1½-cubic-yard bucket on Littlejohn Creek 2 miles northwest of Knights Ferry, sec. 15, T. 1 N., R. 12 E., M. D. The same equipment was used on the adjoining Jack Welch Ranch placer. In 1941, operations ceased and the equipment was removed from the district.

La Grange Gold Dredging Company, with offices at 1805 Mills Tower, San Francisco, has No. 4 dredge in operation adjacent to the Tuolumne River in sec 31, T. 3 S., R. 13 E., M. D., 8 miles west of the town of La Grange. This dredge possesses the longest continuous operating history of any in the state, starting in 1907. It was twice rebuilt by the Yuba Manufacturing Company and has dredged 70,000,000 cubic yards of material. The only long shutdown was from October 1942, to September 1945, owing to the War Production Board's Limitation Order L-208.

This dredge has a wooden hull displacing between 1,300 and 1,400 tons. It is equipped with a 10-cubic-foot bucket line with 62 buckets

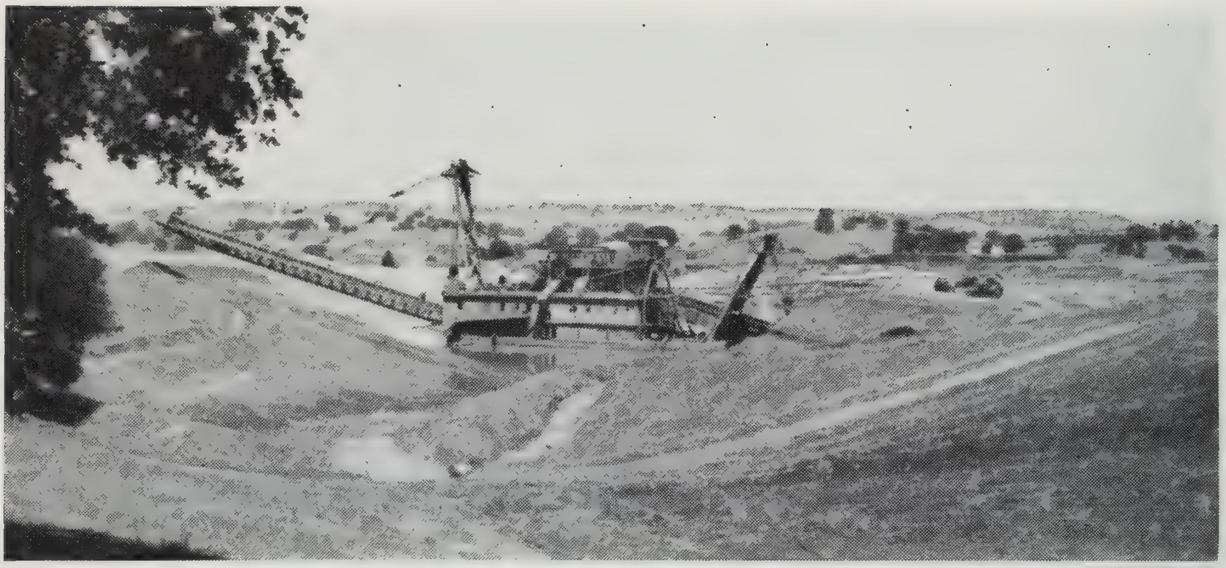
---

[7] Allen, Victor T., The Ione formation of California: Univ. California Dept. Geol. Sci. vol. 18, p. 348, 1929.

[8] Lindgren, Waldemar, The Tertiary gravels of the Sierra Nevada of California: U. S. Geol. Survey, Prof. Paper 73, p. 201, 1911.

A, PLANT OF BARIUM PRODUCTS, LTD.

B, LA GRANGE NO. 4 DREDGE



A, TUOLUMNE DREDGE

B, AGGREGATE PLANT OF J. C. SCANLON

mounted on a digging ladder approximately 75 feet long. The trommel is perforated with $\frac{1}{4}$- to $\frac{5}{8}$-inch tapered holes. Hungarian riffles are used on the gold-saving tables. A 600-horsepower connected load is supplied with electric power by the Turlock Irrigation District. The dredge operates three shifts per day with a total crew of 28 men.

Placer Properties Company, P. O. Box 532, Oakdale, operated a dragline dredge from August 1939, to December 1943. The idle dredge, partly dismantled, stands in sec. 4, T. 2 S., R. 11 E., M. D., on the north side of the Stanislaus River at Whitman's Station, $4\frac{1}{2}$ miles east of Oakdale. The use of a dragline excavator and the use of a shaking screen rather than a trommel screen in the washing plant are interesting features to note on this operation. This dredge has been inactive for the past 3 years, and no immediate plan exists for resuming operations.

Tuolumne Dredge. This Johnson dredge (rebuilt by Yuba Manufacturing Company) was put in operation on June 15, 1938. In 1939 when the operating company was reorganized, Estey A. Julian became agent-manager in charge. R. J. McGuire is the present resident superintendent at La Grange. The dredge is located in sec. 31, T. 3 S., R. 14 E., M. D., $1\frac{1}{2}$ miles south of the town of La Grange.

The dredge section is exceptionally difficult to work, for the Pleistocene [9] river channel is very compact. This fact, together with the presence of many large boulders in a dredge section composed of 80 percent sand, is only part of the problem encountered. The working bank has a maximium total height of 110 feet. Another problem is introduced by the necessity of removing up to 90 feet of barren material. This overburden consists mainly of fine-grained waterlaid volcanic ash. Fifty feet of stripping is done with three tractors and two carryalls to the approximate level of a barren gravel stratum. Twenty to forty feet of additional barren ash is present which is run through the dredge without the addition of water. This method allows the material to go through the trommel and onto the stacker, eliminating much of the former wear on the gold-saving tables and the addition of excessive "fines" to the dredge pond.

The dredge is powered with 1820 rated horsepower. Three 500 kilovolt-ampere transformers aboard the dredge step down the 11,000 volts to 440 volts for distribution. Power is supplied by the Turlock Irrigation District and carried to the dredge by a submerged power cable.

The 144-foot digging ladder is equipped with 100 12-cubic-foot dredge buckets. The dredge is now digging 61 feet below water level and carries a 30-foot bank. A special high-head pump connected to a 300-horsepower motor delivers water (at 200-feet head) to a 3-inch hydraulic giant on the bow gantry. This giant is used to cut the high-front bank down to approximately 10 feet above the water level. Hungarian riffles in double-decked sluices furnish 4,500 square feet of riffle area.

After the dredge capsized in April 1941, 8-foot pontoons were installed on both sides of the hull, to achieve greater stability.

Although shut down for a short period by the War Production Board, the dredge was permitted to stay in limited operation throughout most of the war years. In 1945, three-shift operation was resumed. A 40-man crew is now employed.

---

[9] Hard digging: Mining World, vol. 8, no. 2, pp. 24-26, Feb. 1946.

2—71637

C. F. Vanciel operated a dragline dredge equipped with a $1\frac{1}{2}$-cubic-yard bucket in the Knights Ferry district in 1941 and 1942.

Yuba Consolidated Gold Fields, with offices in the Balfour Building, San Francisco, operated a dredge with 69 9-cubic-foot connected buckets and electric drive in La Grange district starting in December 1941. Located in sec 34, T. 3 S., R. 12 E., M. D., this Waterford dredge was shut down in October 1942 by Limitation Order L-208. When general conditions improve, the plan is to resume operation of this dredge.

Magnesite

Bald Eagle mine in sec. 32, T. 8 S., R. 7 E., M. D., was operated under lease by the Gustine Magnesite Company during 1917 and 1918, producing approximately 2,000 tons of ore at that time. Plastic Magnesite Company operated this property in 1920 and 1921. Reopened in 1930 by the Westvaco Chlorine Products Company, it was operated until 1944. During this period the Bald Eagle mine produced a large quantity of good-grade magnesite. The ore body is now exhausted and all equipment has been removed from the workings.

G. L. Fenster et al. owned a group of five claims in sec. 22, T. 6 S., R. 5 E., M. D., adjoining the Red Mountain magnesite mine. No development work has been reported on this group.

Promberger property, 991 acres of patented land, is situated 14 miles west of Patterson. The property is on Del Puerto Creek and is crossed by the road following the road-bed of the former Patterson and Western Railroad to the foot of Red Mountain. The deposit shows on the surface for a width of 700 to 1,000 feet and for a length of nearly 2 miles. The material is soft hydromagnesite which can be dug with a spade. It shows no change in character in the face of the longest tunnel (about 100 feet in length).

The material contains about 25 percent silica, but possibly the silica may be removed by a simple log-washing operation.

Red Mountain magnesite mine was discovered in secs. 17 and 18, T. 6 S., R. 5 E., M. D., in 1915. The original company was the Red Mountain Magnesite Company, later called the W-K Company. In January 1922, they reorganized as the California Magnesite Company, and operations were continued until 1932. After a short period of idleness, Westvaco Chlorine Products Company operated the Red Mountain magnesite mine under lease from 1935-37. After 460 tons of crude magnesite were shipped in 1942 by Johnson & Son to Westvaco's calcining plant near Patterson, the mine was again closed. Total production of about 140,000 tons of good-grade magnesite is credited to this mine.[10]

Two adits intersect three vertical ore shoots. Approximately 50,000 tons were mined above the upper level prior to 1923. Production was principally from large lenses of ore in a glory-hole area at the north end of the mine. A second adit was put in 195 feet below the first level. The north ore body has been mined to the lower level, but the central and south-end ore shoots have remained unexploited between the two levels. A reserve of between 27,500 and 44,500 tons is indicated.

[10] Laizure, C. McK., Stanislaus County: California Min. Bur. Rept. 21, pp. 208-210, 1925.

Manganese

The manganese ore bodies of Stanislaus County are of sedimentary origin, tending to aline themselves in certain favorable stratigraphic horizons in the Franciscan cherts. White or green cherts seem to be the most favorable for the occurrence of the manganese ore. It has been found, however, in the red cherts to a limited extent. The ore bodies are generally flat and lie parallel to the bedding. The main mineral of the primary ore is rhodochrosite, with hausmanite sometimes replacing it. Bementite is a primary manganese silicate that is common to these deposits, especially disseminated in the outer zone.

There are 29 known deposits of manganese in Stanislaus County,[11] few of which have produced any appreciable tonnages.

During the past two World War periods, manganese ore was produced because of the exceptional demand.

The Buckeye mine is second only to the Ladd mine (San Joaquin County) in production of manganese ore in the state. During the last war period, 13 mines were worked for manganese ore in Stanislaus County. Of the properties operated, the only appreciable production was from the Buckeye, Tip Top, Liberty, Peter Moy, Hamilton, and Gerber mines. About half of the ore produced was sold to the General Dry Battery Company's plant near Patterson. The rest was shipped to Metals Reserve Company stockpiles at Sacramento and Tracy.

With the end of the emergency demand for manganese, the War Production Board recommended a shut-down of operations. The ore specifications were changed effective June 30, 1945. In the same year (1945), the General Dry Battery Company's war-emergency plant near Patterson was dismantled and shipped East. These developments brought an end to the current history of the exploitation of the deposits.

Buckeye mine is located in sec. 3, T. 5 S., R. 5 E., M. D., on a branch of Hospital Creek southwest of Vernalis. This property is owned by the Winship Estate, 350 Post Street, San Francisco.

First mining by open-cut methods revealed an ore body 20 feet wide and over 75 feet long. The Suffern Company of New York, lessees in 1918-19, installed a half-mile aerial tramway, which transported the ore from the mine to loading bunkers for truck haulage. The ore body was developed by a 300-foot shaft and two haulage levels. During the 1918-19 period of activity, approximately 14,000 tons of ore were produced.

The Buckeye mine was leased from 1940-45 by Verner Allen. Old workings were enlarged and a third level driven below 300 feet. The lower workings are in carbonate ore (rhodochrosite). A large reserve of ore better than 30 percent manganese remains in this mine.

Liberty mine is located in sec. 36, T. 4 S., R. 5 E., M. D., about 10 miles west of Westley.

This deposit was first worked in 1924 by the Ferro-Manganese Company. The upper adit is approximately 250 feet long, from which the vein has been stoped to the surface. The width of the vein is 4 to 6 feet. A second adit was driven 105 feet below the first level as a crosscut to the vein. This property remained idle from 1926 to 1941. The Liberty and Peter Moy mines were put into production by the Humphreys Gold

[11] Jenkins, Olaf P., Manganese in California: California Div. Mines Bull. 125, 387 pp., pl. 1, 1943.

Corporation early in 1942; their lease was turned over to Explorers Inc., in 1944. Barker Corporation, the operating company for Explorers Inc., worked the properties until 1945.

The total production of manganese ore from Stanislaus County amounts to approximately 40,000 tons, 24,000 tons of which were produced in the 1940-45 period. No mining has been done since 1945, and all equipment has been removed from the workings.

Mineral Paint

Yellow ochre has been known and mined intermittently for many years in the Knights Ferry district. The Voyle mine in NE¼ sec. 29, T. 1 S., R. 12 E., M. D., had an unbroken annual production record from 1925 through 1929. This property shipped 300 tons of yellow ochre in 1942. Demand for the material has not justified production since that time.

The Bartlett Ranch deposit, Weidman Ranch deposit, and the California Ochre Mining Company's deposit, all in sec. 17, T. 1 S., R. 12 E., M. D., have long been abandoned. The plastic clays and ochres of this district are confined to the Ione formation.[12]

Natural Gas

T. E. Cooper, R. F. D. Rt. 1, Box 99, Waterford, is the owner of a well in sec. 34, T. 3 S., R. 11 E., M. D., that supplies 25 to 30 customers in Waterford with methane gas. This well was drilled for Cooper in 1937 by the Osterburg Bros.

Osterburg Bros., well drillers, River Road, Rt. H, Box 1508, Modesto, in an attempt to find artesian water, drilled a well in 1926 on the south bank of the Tuolumne River half-way between Modesto and Hughson. After drilling 1,380 feet, they abandoned this well. It was noted at the time that an inflammable gas was being emitted. In 1931, the well was developed, and the gas piped to several neighboring homes. At the present time, Osterburg Bros. have three wells producing an estimated 40,000 to 50,000 cubic feet per day of methane gas with varying amounts of hydrogen. A condensing tank is used to remove water from the gas produced at each well before distribution. One-hundred customers use this gas for domestic purposes.

Standard Oil Company of California has two wells producing natural gas from the Vernalis field.[13] Both wells were completed in 1941 in sec. 25, T. 3 S., R. 6 E., M. D. One well is in San Joaquin County, and one well is in Stanislaus County. Production is from Cretaceous sands at a depth of about 4,000 feet. A reserve of 9,482,000,000 cubic feet of gas has been estimated for this field as of July 1, 1945. The production from these wells is supplied at Vernalis to the Pacific Gas and Electric Company's pipe line.

Quicksilver

Quicksilver was noted prior to 1880 in the Franciscan sandstones of Stanislaus County. Cinnabar is the only ore mineral and usually is found

---

[12] Allen, Victor T., The Ione formation of California: Univ. California, Dept. Geol. Sci. Bull., vol. 18, p. 359, 1929.

[13] Estimate of the natural gas reserves of the State of California as of January 1, 1946: Railroad Comm. of the State of California, and California Div. Oil and Gas, pp. 57-58, 1946.

as a thin coating on fracture surfaces. Attempts at production have been limited to times of high prices for this metal. The Summit mine, having produced 200 flasks, is responsible for practically all of the quicksilver gained from Stanislaus County.[14]

Adobe Valley mine (formerly the *Stanislaus mine*) is located in sec. 24, T. 6 S., R. 5 E., M. D., and sec. 19, T. 6 S., R. 6 E., M. D., 3 miles from Del Puerto Creek road and the junction of Del Puerto and Adobe Creeks. This property was in operation from 1884-88. During this period a two-compartment shaft was sunk to a depth of 180 feet and four development drifts were put in. This property was idle until 1940 when it was leased by Peter Saracco of 1816 Seventeenth Street, San Francisco, from Paul Gerber of Livermore, the present owner. The old shaft was unwatered and retimbered to a depth of 115 feet. The old levels were cleaned out and enlarged, developing a fair tonnage of ore averaging 7.65 pounds of quicksilver per ton.[15] In 1941 a 50-ton modern reduction plant was installed. A bunkhouse and cookhouse were built to accommodate from 25 to 30 men. A. C. McLain was superintendent at this property until 1944 when operations ended. All equipment and machinery were removed, and the property remains idle.

Crocker-Winship prospect in sec. 31, T. 5 S., R. 5 E., M. D.; the *Gagax claims* on Mount Boardman in the northwestern corner of the county; the *International mine* in sec. 3, T. 8 S., R. 6 E., M. D.; and the *Newhall mine* (formerly *Deer Park*) in sec. 32, T. 5 S., R. 5 E., M. D., are all old prospects that were never completely developed. No appreciable amount of metal was ever produced from them.

Orestimba mine (formerly *Palo Alto mine*). The Orestimba Mining Company owned a group of 22 claims in sec. 28, T. 7 S., R. 6 E., M. D., about 25 miles southwest of Crows Landing. There is a poor road for 20 miles and then 5 miles of trail to the mine. A shaft 75 feet deep on this property is said to be in high-grade ore at the bottom. Magnesite also occurs on the claims, but it has been only slightly prospected. This property was operated during the first World War and has been idle since that time.

Summit mine (formerly the *Summit-Grayson group* and part of the *Phoenix mines*) is located in sec. 20, T. 6 S., R. 5 E., M. D., and is owned by Emma Rose of New York and E. S. McCurdy of San Francisco. The property is near the Stanislaus-Santa Clara county line and is 39 miles south of Livermore and 26 miles west of Patterson.

Three crosscut drifts are connected by raises and winzes. Three zones of mineralization are present. The main vein contains ore varying from 0.25 to 0.30 percent quicksilver. Overhand stopes were used. At the present time most of the workings are inaccessible because of caving. A 50-ton Scott furnace was built in 1902-03, and from September 1915 to June 1916, the mine and mill were again put into operation. Since that time

---

[14] Hawkes, E. H. Jr., Wells, F. G., and Wheeler, D. P. Jr., Chromite and quicksilver deposits of Del Puerto area, Stanislaus County, California: U. S. Geol. Survey Bull. 936-D, pp. 104-110, 1942.

See also: Bradley, W. W., Quicksilver resources of California: California Min. Bur. Bull. 78, pp. 197-199, 1918.

[15] Peter Saracco, oral communication.

the property has remained idle. Total production to date has been nearly 200 flasks.

Winegar prospect (formerly the *Orestimba group* and part of the *Phoenix mines*) is located in secs. 25, 35, and 36, T. 6 S., R. 5 E., M. D., and includes a large acreage of patented land. This property is owned by Emma Rose of New York and E. S. McCurdy of San Francisco. The workings are in sec. 25, approximately 1½ miles south of the Adobe Valley mine. Mining was done by drifts in a 5-foot fracture zone. The limits of mineralization were reached and although one stope was mined, no ore was shipped from the property.

Silica

Hammond property, in sec. 4, T. 6 S., R. 6 E., M. D., is the only property in Stanislaus County that has produced silica for industrial purposes, excluding the quartz sands mentioned later under *Stone Industry.*

This property was owned by the California Silica Company in 1912. The ledge of quartz is in Del Puerto Canyon about 12 miles west of Patterson, and is comparatively pure. The property was located as the Silica No. 1 by William N. Hammond about 1924. In 1943 silica was sold to H. J. Kaiser Company, and some quartz crystals were sold to the United States Bureau of Standards.

Silver

In 1875-76 an arrastre was operated by Mexicans in Washington Canyon, sec. 3, T. 6 S., R. 6 E., M. D., which joins Del Puerto Canyon about 8 miles from its mouth.

A silver claim called the *None Such,* located in sec. 35, T. 5 S., R. 6 E., M. D., on a small branch of Del Puerto was worked in 1869. A vein of low-grade silver ore is said to have been discovered in Ingram Canyon.

Stone Industry
(Miscellaneous Stone Products, Crushed Rock, Gravel and Sand)

Toni Francisco of Crows Landing produces an unscreened aggregate from Orestimba Creek dry wash in sec. 3, T. 7 S., R. 8 E., M. D. He uses a small gasoline-driven truck loader and operates intermittently.

Gravel Products Company, Hughson, located in sec. 1, T. 4 S., R. 10 E., M. D., is leased and operated by S. C. Pierce and son. A drag-line slusher draws to a hopper that loads a 2½-cubic-yard car on an inclined track, which, in turn, dumps onto a 3- by 8-foot double-deck vibrating screen. The three standard screen products are produced. All oversize (plus one inch) is stockpiled. Total electric power used is 100 horsepower. A maximum shift production of approximately 500 cubic yards is possible.

Nora Hamilton Estate, Westley, California, owns property in sec. 36, T. 4 S., R. 6 E., M. D., 5 miles west of Westley on Ingram Creek, containing sand and gravel suitable for concrete aggregate. Hubert H. Everist Sr., 604 Mission Street, San Francisco, was preparing to process this material in January 1947 for use in construction of the Delta-Mendota canal.

Hughson Gravel Plant owned by Fox Bros. and leased by Edward Klein, 301 North Santa Cruz Avenue, Modesto, is located in sec. 2, T. 4 S., R. 10 E., M. D. A 1½-cubic-yard highline excavator is used to feed

a vibrating screen which produces the three standard products: sand, minus $\frac{1}{4}$-inch; pea rock, minus $\frac{1}{2}$-inch plus $\frac{1}{4}$-inch; and inch-rock, minus 1-inch plus $\frac{1}{2}$-inch. All oversize goes through a primary jaw crusher and then through a gyratory crusher. The reduced material is lifted by a bucket elevator and returned to the vibrating screen.

The sand is washed with a "sand drag" type classifier, which consists of a link belt fitted with metal strips mounted at right angles. The classifier is mounted with a 20 degree slope. Owing to the raking action of the "paddles", washed sand is discharged at the upper end. At the time that this operation was visited, the equipment was being moved to a new concrete foundation located in a more favorable position to exploit a large bar in the Tuolumne River channel.

Johnson Brothers, P. O. Box 123, Modesto, are preparing to operate a dry pit in an old channel of the Tuolumne River in sec. 36, T. 3 S., R. 10 E., M. D. A dragline excavator is used to load a 5-cubic-yard dump truck that feeds the main hopper. The aggregate will be lifted by a bucket elevator to a small hopper from which it will be carried to a vibrating screen by a belt conveyor. The sand is to be washed with a sand-drag type classifier. No crushing will be necessary. Five products are to be produced. They will be plaster sand, minus $\frac{1}{8}$-inch; concrete sand, minus $\frac{1}{4}$-inch; "Birdseye," plus $\frac{1}{8}$- and minus $\frac{1}{4}$-inch; pea gravel, plus $\frac{1}{4}$- and minus $\frac{3}{8}$-inch; inch rock, plus $\frac{3}{8}$- and minus 1-inch. All equipment will be powered by gasoline engines. Operations will be carried on with a three-man crew. The equipment was in place when this property was visited but production was not yet under way.

Frank B. Marks & Sons, 203 Berverdor Street, Tracy, have a large pit in the dry bed of Orestimba Creek in sec. 10, T. 7 S., R. 8 E., M. D. It is only in intermittent production, for large stockpiles of the three standard products are kept on hand. A portable crusher and a bucket excavator are brought in when the plant is to be operated. Washing is done with well water.

Putman Sand & Gravel Company, P. O. Box 486, Modesto, is operating a large pit in an old channel of the Stanislaus River. Being on the north side of the Stanislaus River channel, this pit is in San Joaquin County, half a mile north of the town of Riverbank.

This company has installed a highline excavator on the bank of the Tuolumne River next to the Seventh Street bridge in Modesto (sec. 32, T. 3 S., R. 9 E., M. D.). Plaster sand is the only product of this one-man plant.

J. C. Scanlon, Elfers Avenue, Patterson, produces road material in the dry wash of Orestimba Creek in sec. 10, T. 7 S., R. 8 E., M. D. A scraper conveyor is used to feed a hopper fitted with a grizzly at the top. The aggregate is carried by a conveyor belt to a dry trommel which has 1-inch holes. The minus 1-inch material is transported to a metal loading bin by means of a small bucket elevator.

C. V. Skove and J. Wychopin, R. F. D. Rt. 1, Box 27, Turlock, produce unscreened aggregate, mainly sand, from the bed of the Tuolumne River in sec. 33, T. 3 S., R. 10 E., M. D. A small loading hopper is fed by a highline excavator equipped with a 1-cubic-yard bucket. A 41-horsepower gasoline power plant is used for this operation.

Charles Warner 247 Yosemite Boulevard, Modesto, operates two highline excavators, both of which are mounted on concrete foundations. One is located in sec. 32, T. 3 S., R. 11 E., M. D. The other is to be moved from sec. 5, T. 4 S., R. 11 E., M. D., to the south bank of the Tuolumne River in sec. 33, T. 3 S., R. 11 E., M. D. In this new location, not only will a larger reserve of material be available, but a reduction in the truck haulage distance to southern points will be effected.

The plant now in operation is equipped with a $2\frac{1}{4}$-cubic-yard highline excavator bucket and is electrically operated, using a total of 200 horsepower. A vibrating screen separates the three standard products: sand, pea rock and inch rock, sending the oversize (greater than $1\frac{1}{2}$-inch) to a jaw crusher. The discharge from the jaw crusher is returned to the screens. The sand (minus $\frac{1}{4}$-inch) is washed with a rake classifier. A gyratory crusher is used to reduce material smaller than $1\frac{1}{2}$ inches in diameter. The crusher is fed from a hopper supplied by truck. The discharge from the gyratory crusher feeds into the same bucket elevator that receives the discharge from the jaw crusher. A two-man crew operates this plant, but the present plan is to use a third man for truck driving, relief, and emergency duty [16].

[16] Since this was written, this active plant was undermined and collapsed.

VANADIUM

By W. B. Winston*

PROPERTIES

The metallic element vanadium (V) is grayish-white in appearance, nonmagnetic, and has a high electrical resistivity. It is one of the least volatile metals at the melting point and is extremely difficult to reduce to the pure metallic state from its oxides. Though relatively rare, vanadium is found in a number of minerals. Of these, the principal sources are patronite, descloizite, cuprodescloizite, mottramite, vanadinite, carnotite, and roscoelite.

Patronite (rizopatronite) is a vanadium sulfide intimately associated with carbonaceous material, perhaps VS_4. It occurs in this form, with more or less oxidized modifications, in a complex mixture of mineral substances among which are "quisqueite" and "bravoite," only in the high Andes of Peru. According to Hewitt,[1] the deposit is apparently an extreme phase of hardened vanadium-bearing asphalt.

Descloizite is a vanadate of lead with zinc, $R_3V_2O_8R\ (OH)_2$, R= lead, zinc chiefly, and usually in the ratio 1:1 approximately. Cuprodescloizite is a variety with about half of the zinc replaced by copper. Mottramite may be considered as another variety in which the zinc is almost entirely replaced by copper. It is found in small orthorhombic crystals, often drusy, also massive, fibrous radiated with mammillary surface. Hardness is 3.5; specific gravity, 5.9 to 6.2; color, cherry-red and brownish red to light or dark brown, black; streak, orange to brownish red or yellowish gray. It is easily fusible. Descloizite is a mineral of secondary origin found occasionally in lead-zinc deposits.

Vanadinite is a chlorovanadate of lead, $(PbCl)Pb_4\ (VO_4)_3$, vanadium pentoxide 19.4, lead pratoxide 78.7, chlorine 2.5. It crystallizes in the hexagonal system; crystals are prismatic, with smooth faces and sharp edges; sometimes cavernous, the crystals hollow prisms; also in rounded forms and in parallel groupings like pyromorphite; in implanted globules or incrustations. Fracture is uneven, or flat conchoidal; brittle. Hardness is 2.75 to 3; specific gravity, 6.66 to 7.10; luster of surface of fracture, resinous; color, deep ruby-red, light brownish yellow, straw-yellow, reddish brown; streak, white or yellowish. It is an uncommon mineral usually found in altered lead deposits.

Carnotite, named after the French scientist Carnot, is a vanadate of potassium and uranium, containing small amounts of radium; a highly complex mineral, approximately, $K_2O.2UO_3.V_2O_5.2H_2O$. It crystallizes in the orthorhombic system. It is found in the form of a yellow crystalline powder, as powdery incrustation, in loosely cohering masses or as an impregnation in sand or sandstone. Common associates are malachite, azurite, biotite, and magnetite.

Roscoelite, sometimes called vanadium mica, is essentially a muscovite in which vanadium has partly replaced the aluminum. It crystallizes in the monoclinic system in minute scales with micaceous structure

* Junior Mining Engineer, California State Division of Mines.

[1] Hewett, D. Foster, The story of Minas Ragra—premier vanadium find: Eng. Min. Jour., vol. 148, pp. 59-63, 1947.

and cleavage. Hardness is 2.5; specific gravity, 2.97; color is clove-brown to greenish brown; luster is pearly. A vanadium-impregnated sandstone in Colorado and Utah is often erroneously called roscoelite.

Of the 60 known vanadium minerals, sulvanite, a copper vanadium sulfide, patronite, and roscoelite are original minerals; all the others are products of the oxidized zone. Most of the oxidized minerals are highly colored greens, yellows, reds, and browns—and some are beautifully crystallized.

TESTS

With borax in the oxidizing flame, vanadates give a yellow bead when hot which changes through yellowish green to nearly colorless when cold. In the reducing flame, vanadates in a borax bead give a dirty green color which becomes a fine green upon cooling. With salt of phosphorous (sodium ammonium phosphate), material containing vanadium is yellow to amber color in the oxidizing flame and fine green after being heated in the reducing flame and allowed to cool. Vanadium minerals are decomposed by hydrochloric acid, and the solution becomes reddish brown when hydrogen peroxide is added.

OCCURRENCE

Vanadium is one of the most widely distributed of the elements, occurring in small percentages in granites, sedimentary rocks, and clays, and also in many iron, lead, and copper ores, bitumens and petroleums. In order of importance, sources of vanadium consumed in the United States are: 1) Patronite ores from Minasragra, Peru, formerly the world's chief supply of vanadium. The patronite has now all been mined, and the present vanadium ore is largely a mixture of hydrous calcium vanadates and the hydrous sulfate. 2) Miscellaneous mixed ores, mainly from southwestern United States in which vanadinite is the usual vanadium carrier. It is found associated with lead, zinc, and copper in numerous vein deposits in New Mexico and Arizona and in smaller deposits in Nevada, Montana, and California. 3) Carnotite from southwestern Colorado and adjoining parts of Utah. Associated with the mineral, which occurs in loosely cemented sandstones, are several other vanadium minerals, chief among which is a micaceous material not definitely identified. The deposits are mostly small and carry from 2 to 4 percent vanadium oxide. The ore is mined not only for its vanadium and uranium content but also for the small amount of radium it contains. Near Mauch Chunk, Pennsylvania, carnotite occurs in a coarse-grained conglomerate in which it is thoroughly but unevenly distributed. There is no other mineral just like carnotite, and it is mainly confined to this country.

A vanadium-bearing material similar to patronite was noted in Oklahoma and Utah asphaltite.

Roscoelite was formerly the chief domestic source of vanadium but the largest deposit, at Rifle, Colorado, is now exhausted. A vanadium-impregnated sandstone often erroneously called roscoelite occurs in Utah. Descloizite, cuprodescloizite and mottramite are found in commercial quantities in Rhodesia and southwest Africa. The lead-zinc ores at Broken Hill, North Rhodesia, contain considerable descloizite and vanadinite, which go in part into the zinc concentrate.

In California vanadinite has been found in Kern County, near Searles Lake, and with galena and mimetite, near Randsburg. In San Bernardino County, it occurs with cerussite and cuprodescloizite in the Vanadium King mine; and it was found near Moore Station on the U. P. Railroad. Roscoelite, interlaminated with gold, was found in El Dorado County near Coloma; and it was found in Big Red Ravine near Sutters Mill.

A possible domestic competitor for market is the vanadium contained in the phosphate rock of Idaho, Montana, Utah, and Wyoming. Soots from oil-fired furnaces burning Mexican or Venezuelan petroleum carry noteworthy amounts of vanadium, which also occurs in numerous asphalts and in many bituminous coals. Vanadium is often found in titaniferous magnetites and is extracted from open-hearth and converter slags at steel works. In Italy, some vanadium is recovered from the caustic-soda solutions in the Bayer process for purifying bauxite.

PREPARATION

Vanadium was first discovered in brown lead ore by the Mexican chemist Del Rio, in 1801. In 1830 the Swedish chemist, Sefstrom, detected it in some remarkably soft, ductile iron produced from an ore at Taberg, Sweden. He named it "vanadium" after the ancient Scandinavian deity "Vanadis." In 1869 the metallic element was isolated by Roscoe for the first time. In 1896 vanadium was first used experimentally in the manufacture of armor plate in France. It was not until the comprehensive investigation of Arnold in 1900-01 that vanadium began to receive attention as an alloy for steel. In 1904 Sanky and Smith presented a paper before the British Institute of Mechanical Engineers giving the results of their investigations on chromium-vanadium steels. This paper really marks the beginning of vanadium steel as a commercial product.

Vanadium is reduced from its ores to form ferrovanadium either directly by means of carbon in the electric furnace or from previously prepared vanadium oxide by the silico-thermic method in the electric furnace, or by the alumino-thermic method without the application of external energy. Vanadium oxide for these reductions and for chemical uses is prepared by roasting ores with sodium compounds to form sodium vanadate followed by precipitation with sulfuric acid from the neutralized vanadate solution.

Vanadinite may be concentrated on tables because of its high specific gravity. Carnotite has been concentrated by air blast during the crushing process. Roscoelite is too light to permit its separation by gravity concentration. In the separation of vanadium from carnotite, the radium and uranium are removed first; then the vanadium is precipitated from a neutral solution by ferrous sulfate as ferrous vanadate. Vanadium may be recovered from phosphates by a patented process in which the vanadium content of a phosphoric acid solution is converted to vanadium pentoxide and then extracted by means of a selected solvent.

USES

No important industrial uses of the pure metal have been developed. The principal use of vanadium is as an alloy in steels where great toughness and torsional strength are needed. Vanadium in steel lessens coarse

crystallization and grain growth and influences the manner of solution or precipitation of the carbide in or from the solid solution, iron-rich matrix. Vanadium steels are readily cast, forged, or rolled. In machining, these steels are no more severe upon cutting tools than other alloy steels of equal strength or hardness. In tool steels employing large amounts of vanadium the fine grain size is relied upon for toughness at high hardness; whereas the carbide is effective in producing cutting qualities, abrasion resistance, and permissible high tempering temperatures.

The vanadium-alloy steels are carbon-vandium steels, chromium-vanadium steels, manganese-vanadium steels, nickel-vanadium steel castings, manganese-chromium-vanadium steel, silicon-vanadium spring steel, vanadium nitriding steels, and vanadium tool steels. The many uses and the properties of these steels are given in great detail in various engineering handbooks, notably Metals Handbook. A minor quantity is employed as a catalyst in the manufacture of sulphuric acid in the form of ammonia metavanadate and in the nonferrous, glass, ceramic, and color industries.

MARKETING

Nominal quotations (the larger producers also being consumers) on vanadium ore according to Engineering and Mining Journal Metal and Mineral Market, January 6, 1947, was 27½ cents per pound of V_2O_5 (vanadium pentoxide) content; on ferrovanadium, \$2.70 to \$2.90 per pound of vanadium content, delivered.

SELECTED REFERENCES

As vanadium is not commonly used like lead, zinc, iron, or copper, information is correspondingly less widespread. The references listed below, some of which contain extensive bibliographies, furnished the data presented in this paper, and are suggested as sources for additional information on vanadium.

Taggart, Arthur F., Handbook of mineral dressing, ores, and industrial minerals, Wiley Engineering Handbook Series, John Wiley & Sons, Inc., New York, 1945.

Strauss, Jerome, and Norris, G. L., Vanadium steels, in Metals handbook, 1939 ed., pp. 592-611, American Society for Metals, Cleveland, Ohio, 1942.

Peele, Robert, and Church, John A., Mining engineers' handbook, 3d ed., Wiley Handbook Series, John Wiley & Sons, Inc., New York, 1941.

Eschbach, Ovid W., Handbook of engineering fundamentals, Wiley Engineering Handbook Series, vol. I, John Wiley & Sons, Inc., New York, 1936.

Pardee, J. T., Vanadium in sedimentary rocks, in Ore deposits of the Western States (Lindgren volume), pp. 455-480, Am. Inst. Min. Met. Eng., 1933.

Hess, Frank L., Vanadium: U. S. Bur. Mines Inf. Circ. 6572, 8 pp., 1932.

Doerner, H. A., Notes on extraction and recovery of radium, vanadium, and uranium from carnotite: U. S. Bur. Mines Rept. Inv. 2873, 12 pp., 1928.

Hess, Frank L., New and well known minerals from the Utah-Colorado carnotite region: U. S. Geol. Survey Bull. 750, pp. 63-78, 1925.

Hess, Frank L., Carnotite near Green River, Utah: U. S. Geol. Survey Bull. 530, pp. 161-164, 1913.

Hess, Frank L., Vanadium in the Sierra de los Caballos, New Mexico: U. S. Geol. Survey Bull. 530, pp. 157-160, 1913.

Hewett, D. Foster, Vanadium-deposits in Peru: Am. Inst. Min. Met. Eng. Trans., vol. 40, pp. 274-299, 1910.

FIFTY YEARS OF OPERATION BY THE MOUNTAIN COPPER COMPANY, LTD., IN SHASTA COUNTY, CALIFORNIA

By William F. Kett *

OUTLINE OF REPORT

* General manager, The Mountain Copper Company, Ltd.; retired October 1946. Manuscript received for publication January 1947.

ILLUSTRATIONS

INTRODUCTION

General Geology of the Iron Mountain Region

The Iron Mountain copper area is located about 12 miles northwest of Redding, in Shasta County, California. Principal igneous rocks of the region are alaskite porphyry and meta-andesite, in order of their importance as host-rocks for the ore. If sedimentary rocks existed in the area, they have been eroded away.

It is the accepted theory that the alaskite associated with the Iron Mountain ore body was intruded between a floor of previously intruded alaskite, and a roof of flat-lying sediments, and was limited locally by two distinct converging walls (faults antedating the original Iron Mountain ore body). Shortly after intrusion there was locally intense crushing, resulting from cooling of the mass. The highly crushed zone allowed the entrance of solutions, which finally replaced the broken country rock with primary pyrite and some inclusions of chalcopyrite.

The sediments then were eroded. Subsequent oxidation of the sulphide produced the copper ore and gossan of the Iron Mountain ''Old mine''. The physical appearance of the gossan overlying the ore body at the old Iron Mountain mine suggested that the copper ore body was originally principally pyrite with some chalcopyrite and small amounts of gold and silver. When sulphides completely oxidize, there must be an abundance of sulphur. Since pyrite has a relatively high sulphur content, it oxidizes easily under proper conditions. In the case of oxidizing pyrite, acidity of the solutions is high, and if no neutralizer is present, limonite will not be precipitated. At Iron Mountain apparently there was more than sufficient neutralizer present, as much of the iron, gold, and silver, and some of the copper, were precipitated within the oxidation zone. In fact, there is considerable evidence of re-precipitated limonite within the gossan mass. As the primary sulphide body was encased on five sides within practically unshattered alaskite, important portions of the copper solutions percolated downward during the oxidation period into the fractured primary sulphide below. The result was a secondary enrichment of the mass, with secondary copper minerals. The unaltered primary sulphides which now remain are found to contain but little of the precious metals, indicating that (1) the greater proportion of gold found in the gossan is principally the result of the change in volume incident to oxidation of the sulphide mass, and (2) that little migration of the gold occurred. There was, however, a concentration of silver in the sulphide capping, and the limonitic gouge existing between the main sulphide body and gossan capping. Silver was also concentrated to a lesser degree in the regular gossan for about 20 feet above the sulphide gossan contact.

It was this concentration of silver that was responsible for the early mining at Iron Mountain.

There is no doubt that, during the oxidation period, the greater part of the original gossan was redissolved and eroded, as the mountainside was precipitous and the rainfall extremely heavy at times. The gossan was principally limonite and hematite, with some magnetite and other ferruginous oxides, and small amounts of quicksilver, arsenic, and selenium. The copper content generally averaged about 0.40 percent.

Description of Iron Mountain Property, 1896

The Iron Mountain property was originally purchased in 1894 by The Mountain Mines, Ltd., an English corporation. The assets of this concern were acquired by The Mountain Copper Company, Ltd., in the latter part of 1896, at which time a brief description of the property was published in connection with a prospectus issued to the public. The following abridged statements from the description indicate the opinions existing at that time regarding the property.

Surface of the Mine. The mine is situated on patented land to which the company has a perfect title. A practically continuous north-trending outcrop or cap of decomposed pyrites, known as "gossan", extends for a distance of 1½ miles from the bottom of Slick Rock Creek up one side of the mountain and down the other to Boulder Creek. At some places this outcrop is as much as 500 feet wide.

Copper Pyrites. Copper pyrites are found directly under the gossan cap and strongly resemble the pyrites masses at the Rio Tinto and Tharsis mines in the south of Spain, except that the Iron Mountain deposit is nearly three times as rich in copper, and in addition contains precious metals of considerable commercial value.

Development. Concurrently with the construction of the narrow-gauge railway from the mine to Keswick, underground work was undertaken on three levels. Cross-cuts were run on each level for 100 feet along the ore body. The width between the walls at the south end measures approximately 300 feet. Such an enormous mass of rich ore is probably unique.

Quantity of Ore in Sight. Careful measurements made by the company's engineer show practically 1½ million tons of ore in sight in one singularly pure and homogeneous mass, entirely free from "horses" or foreign bodies of any kind.

Quality of Ore. An exhaustive sampling shows this ore body to average more than 7 percent copper, and to have a value of about $2.00 per ton in precious metals.

Mining Facilities. The mine is situated on a sharply rising hill, just above Slick Rock Creek, and therefore can be worked by levels; all the ore can be trammed out through slightly declining tunnels, thus avoiding any hoisting or pumping.

Railway. A railway connects the mine with the smelting works, and runs on a uniform down-grade for a distance of about 11 miles, and thence another mile to the Southern Pacific main-line track at the mouth of Spring Creek.

Smelting Operations. Smelting operations are carried on at Keswick.

Fluxes Required in Smelting. It is expected that the quartz needed as flux in smelting the copper pyrites will be obtained from various mines in the district that carry more or less gold, from which a profit will be derived, which would not be the case if barren fluxes were used.

Gossan Ore. The gossan mine above the pyrites has been worked by the previous owners for some years. From their books it appears that from 1889-93 they treated about 38,000 tons of gossan, averaging slightly over 8 ounces in silver. The gold content was not ascertained, as they had no means, by the processes then in use, of saving it. Since the company acquired the property, about 5,000 tons of gossan have been extracted, averaging $8\frac{1}{3}$ ounces of silver and slightly more than 2 pennyweights of gold, equal at the present price of precious metals to about $6.72 per ton of ore. The enormous masses of this gossan existing on the property indicate the possibility they may afford a source of additional revenue in the future.

HISTORY OF OLD IRON MOUNTAIN MINE

Discovery

The early history of the Iron Mountain mine in Shasta County is covered fairly well in old bulletins [1] of the California State Mining Bureau, which also give some details of the first 5 years of copper production, beginning in 1896.

There is no known record of the discovery of the Iron Mountain gossan mass, but it is generally understood that in the early sixties William Magee, a United States land surveyor, noted the enormous capping of gossan on the mountain, and, in association with Charles Camden, secured the property as an iron mine. Until 1879 it was held by these men for its possible future value; in 1879 or 1880, James Sallee is said to have discovered silver in an adjoining ledge, and to have become a partner with Camden and Magee.

Operation as a Silver Mine

Superficial investigation indicated that the gossan capping, where it contacted the sulphides underneath, contained silver, frequently in considerable amounts. Various attempts were made to profitably recover this silver, and finally the so-called "Washoe" process was adopted. For some time thereafter, while the price of silver was relatively high, the operation was quite successful.

The silver-bearing gossan as obtained from underground workings was first crushed to minus $2\frac{1}{2}$ inches, then dried in a rotary kiln and fed to the stamp battery, where it was crushed dry to minus 40 mesh. The mill was equipped with a Brueckner furnace and presumably the crushed ore was mixed with salt and passed through this roaster in order to chloridize the silver. The pulp was then transferred in 4-ton batches to pan amalgamators and treated for about 3 hours, after which sodium amalgam, copper sulphate, and about 200 pounds of quicksilver were added and the charge ground for another 5 hours. After this the batch

[1] Aubury, Lewis E., The copper resources of California: California Min. Bur. Bull. 23, pp. 66-74, 1905.
Aubury, Lewis E., The copper resources of California: California Min. Bur. Bull. 50, pp. 70-78, 1908.

WILLIAM F. KETT

Ramifications of the company are numerous, but this report is confined to the Shasta County activities.

Iron Mountain Railway Company

In 1895 Fielding appointed Gilbert McM Ross superintendent at Iron Mountain, and the underground work was actively pushed. This resulted in the discovery of a large body of sulphide copper ore carrying about 7 percent copper and a couple of dollars per ton in gold and silver values. These favorable developments justified a large operation, and steps were taken early in 1895 to build a narrow-gauge railway to transport the ore to a blast-furnace smelting plant, work on which was undertaken at a point about a mile above the junction of Spring Creek with the Sacramento River.

The construction of the narrow-gauge Iron Mountain Railway was started early in 1895 and completed February 1, 1896. This line was a little over 11 miles in length and, when in full operation, had some 3½ miles of spurs and side tracks in the operating yards and passing-sidings on the main line. Also, some 2 miles at the smelter end of this road had a three-rail system to enable the handling of standard broad-gauge cars from the Southern Pacific Company's main line. The Iron Mountain Railway proper was 36-inch gauge of 40-pound rails. The maximum grade was 3.75 percent on tangents but curves were compensated, according to the degree of curve. The maximum curvature on the road was 34 degrees, and there were many such curves, including the double loop near Iron Mountain.

The engineering and construction of the railroad were under the supervision of M. M. O'Shaugnessy, who also assisted in obtaining a franchise which enabled the line to act as a common carrier. He left before the railway was in operation, going to the Hawaiian Islands, where he was in charge of a project to develop more water for the plantations. He was quite successful and made a great name for himself. He returned to San Francisco and subsequently became City Engineer, which position he held to the time of his death. His life work was, of course, in connection with the Hetch Hetchy water supply for San Francisco.

Keswick Smelter

Gilbert Ross resigned after a few months and was succeeded during the latter part of 1895, by Alexander Hill, an experienced mining engineer from the Rio Tinto mine in Spain, who came out from London as resident manager. He was an able organizer and entitled to much credit for getting the enterprise started on a sound basis. However, he resigned early in 1897 and his place was filled by Lewis T. Wright, who came from England for that purpose.

In the meantime, work had progressed on the smelter erection, and two large blast furnaces had been completed, as well as 80 roasting stalls. The furnaces had a nominal capacity of 300 to 400 tons per day. One of the furnaces started operating in March 1896, but various difficulties were encountered and it was not until the latter part of November 1896 that the second furnace was put in operation. Ultimately the smelting plant at Keswick was increased until at the peak of its operation in 1904 it was treating an average of more than 1,000 tons per day of Iron Mountain sulphide ore, taxing the ability of both the mine and the railway.

The following enumeration of the items in the Keswick smelting plant will give a general idea of its magnitude. There were five water-jacket blast furnaces with a capacity of 300 tons per day each. Furnaces Nos. 1, 2, 3, and 4 had a common stack and a large sheet-iron dust collector, while furnace No. 5 had its own stack and dust chamber. The fine ore was roasted in two banks of Wright-McDougal roasters, each 18 feet in diameter with six hearths. Each bank consisted of four roasters with a separate stack. Two briquetting machines were required to compress roasted fines, as well as the crude fines from the mine and the flue dust, before these could be charged into the blast furnaces; and a large oil-burning pre-heating unit was employed to furnish the hot air essential to the success of the pyritic method of smelting.

Because of the necessity of purchasing siliceous flux, a crushing and sampling plant, and a well-appointed laboratory had to be provided.

Service water for the plant was pumped through a pipe 16 inches in diameter for a distance of about 4,500 feet, from the Sacramento River near the mouth of Spring Creek. The pumping installation included a Babcock-Wilcox steam boiler, a Corliss-Hamilton engine, and an old-style Cornish plunger pump. These involved a large capital expenditure.

Adequate medical attention and prompt service in case of accidents required the maintenance of a well-equipped hospital with a resident physician and trained nurse.

Electric Power

When The Mountain Mines, Ltd., started operations at Keswick in 1895, there was no electric power available, so the company installed a small steam-driven generating plant of its own to supply power for lighting and laboratory purposes. All other power required had to be from steam; but late in 1897 a group from San Francisco, headed by H. H. Noble, called upon the company to interest it in a project they had in mind to bring electric power to the plant at Keswick. They were told that the company would use the power as soon as they could deliver it, and they organized at once and had power available within 12 months. At that time the Keswick smelter was practically the only concern in Shasta County using electrical power, and the new enterprise was first called the Keswick Light & Power Company. Later the name was changed to Northern California Power Company. Their first plant was installed on Battle Creek, a very large stream located in the southeastern corner of Shasta County. Shortly afterward, a second plant was located on Snow Creek, a little to the north. Within a few years the Northern California Power Company was taken over by the Pacific Gas and Electric Company, which has continued since that time to serve the company adequately and efficiently.

Company Buildings

One of the first tasks at Keswick was to erect adequate buildings to provide office accommodations and living quarters. Because of the isolation of the plant, it was also necessary to encourage some degree of social activity and recreation for the company's staff.

The manager's residence was a well-furnished, single-story cottage with seven rooms, two large brick fireplaces, and a wide porch all around the building. It cost, without furniture, about $4,500. Three houses for

the superintendents were also erected. These were of wooden construction, of 4 to 5 rooms, costing about $3,000 each.

The staff quarters consisted of one two-story building of 16 rooms, complete with furnishings, toilets, baths, etc., which cost about $4,500. Also, there was a large mess and entertainment hall which included a large dining room and kitchen, canteen, billiard room, music room, toilets, etc., for the staff, as well as separate quarters for the domestic help. This cost about $6,000 complete.

There were two office buildings, each of two stories. The upper floors were occupied by the general manager, accounting and catering departments, and the engineering and supervising staff. The lower floors were used for hardware and general storage, from which issues were made of all kinds of workaday equipment. Each of these buildings had a heavy loading and unloading platform parallel to the railroad siding in the smelter yard. These two buildings cost about $6,000.

A large general-merchandise store was built at an early date near the southeast corner of the company's property, not far from the adjoining town of Taylor. This store carried men's and women's clothing, a general line of groceries, small hardware, beer, etc. The manager of the store stated that at one time he had a $70,000 stock, and prices were so low that some of the merchants of Redding came out and complained about the unfair competition. This store building cost about $3,000 with counters and shelvings.

Of family cottages there were some 25, each with three or four rooms. These were rather cheaply built, with papered walls, and cost about $600 each. They rented for $10 and $12 per month.

If the building costs mentioned above appear low, it should be remembered that at the time the various structures were erected, both materials and labor were very cheap. Common lumber was $9.00 to $10.00 per thousand, and dressed lumber, such as T. & G. flooring and ceiling, sold around $15.00 per thousand. Good carpenters received from $2.75 to $3.00 per day of 10 hours.

There were two bunkhouses for men, of 16 rooms each. The rooms rented for $1.00 per month, but no bedding was furnished. Also there were a few smaller bunkhouses with side-wall bunks, rent free. At about this time the outside town of Taylor began to build, and all of the overflow of men took up quarters in town, so the company bunkhouses were discontinued. Before the town of Taylor began to grow, an eating house was maintained, but as soon as the employees could get their meals uptown, this was also discontinued. The charge was $18 per month for meals.

During the early period, most of the married staff members lived in the old town of Shasta and drove to and from the mine.

A stable on the property provided for the care of several teams, for there were no "gas wagons" at that time.

Incidentally, during the first 5 years of the Keswick operation, there was a slaughter house located on what was known as the "Nune Ranch." This was a couple of miles from the smelter and provided the cookhouse with beef, pork, mutton, lard, etc.; but sanitary regulations in those days were not too closely observed and the consensus was that smelter smoke was no antidote for slaughter-house odors.

The Town of Taylor

The property of the company in the vicinity of the smelter was known as Keswick, and the Southern Pacific Railway station was also called by that name; but adjoining and immediately to the south there grew up a community that called itself Taylor. Shortly after the company broke ground for the building of its plant, this town started to grow. First came a couple of saloons, then some more, then stores, two very good hotels, several boarding houses, a drugstore, a post-office named "Taylor", a weekly newspaper (*The Mountain Miner*), etc. At the peak of activities, a very good school house was erected to care for some 300 children, under five teachers. Likewise there was a very good church, a livery stable, and, at one time, 30 saloons and other places where drinks were served. Including company employees, this mushroom town had a population of perhaps 1,600 to 1,800, with a town constable, a Justice of the Peace, Justice of the Peace court, and a jail that was always full. An officer of the law who came from San Francisco to look for an ex-convict, remarked that whenever the law wanted to locate a law-breaker or an ex-convict, Keswick and Taylor were considered the most likely places to look.

As regards location of dwellings, experience proved that the south side of Spring Creek was far from what the real estate advertisements would call "desirable residential property" because, being situated on the side of a hill above the smelter, they were occasionally in the line of the sulphur smoke from the roasters and blast furnaces, but this was not fully appreciated at the time they were built and, in any case, there appeared to be no better place for them, except in the same general direction at a greater distance from the smelting and roasting operations.

Recreational Facilities

Near the staff house a tennis court was built. To do this, a rather steep hillside was excavated, the cut at the deepest being perhaps 12 feet. Wooden cribbing was used at the low hillside, and the space between the cut and the cribbing was filled. The court, which was of standard size, had a 12-foot netting around it, and if a ball went over, it was lost for keeps. This court was used a great deal by the staff and visitors, and tournaments were often held between company teams, or a team would come out from Redding, and then a return game at Redding followed. This court cost some $300.

A very good football field, located near Nune Ranch, was used almost every Sunday in good weather. The game played was the English Association, not so well known here in the West; ultimately Redding created a football field and many return games were played. Teams also came up from San Francisco and Berkeley. The one from San Francisco was sponsored by Dunham, Carrigan & Hayden. For the benefit of the English members of the staff, a cricket outfit was bought, and this was a popular game when enough Englishmen could get together.

Another form of entertainment was the game of Fox Hunting, or what could more accurately be called "Paper Chasing." Many of the early staff members had saddle horses and the game was played on the plains across the Sacramento River below Redding. Everybody would gather at a picnic ground, where timber and brush were plentiful and the brush of good height. One rider would be selected as the "fox"; he was

supplied with two bags of well-torn white paper which he would scatter on his way as a trail scent. If the ''fox'' made it home before he was caught he won, otherwise he lost. The ''fox'' had an out-of-sight start before the ''hounds'' took after him.

Wright took an active interest in all these sports and he was a splendid rider. Fielding also seemed to favor them, doubtless because he thought they helped to create an esprit de corps.

A number of young men were sent out from England to fill clerical positions on the staff, and some of them arrived complete with yachting flannels, dinner jackets, and similar impedimenta, accompanied by a mental picture of cruising luxuriously on the Sacramento River, dining in state, and generally living the ''life of Riley.'' When they saw the actual ''wild and wooly'' conditions, with the thermometer at 110 degrees almost every afternoon in the Keswick office during the summer, with torrents of rain in the winter, and found themselves compelled to breathe sulphur smoke both day and night, their homesickness and disappointment can better be imagined than described.

Operation as a Copper Mine

A concise statement of the first 3 years of operation in Shasta County by The Mountain Copper Company, Ltd. (1896-98) was given by M. M. O'Shaughnessy in his article *The Copper Resources of California.*[3]

"*Mines of the Shasta Belt:* I. The Mountain Copper Mine, commonly known as the "Iron Mountain," is at present the only big producer of copper on the Pacific Coast, and the first to be systematically developed in this belt. It was originally discovered by a land surveyor, named Magee, who acquired it on the theory that it was valuable for its iron ores. It was relocated by James Salee, who thought it valuable for its silver ores. They sold the property, in 1886, to some parties, who put up a twenty-stamp mill, and attempted to work the surface gossan ores as a free milling proposition. After spending $100,000 in this experiment, they discovered the ore was too base for successful treatment by that process, and forfeited their payments on the property with its improvements. Until 1895, the property was hawked all over the country and London, in search of a purchaser, and condemned by many alleged experts, until it was brought to the attention of C. F. Fielding, of New York, by Hugh McDonnell, the well-known promoter. After an examination by Mr. Alexander Hill, of London, the well-known mining engineer, the property passed into the hands of the Mountain Mines Co. (Limited), who disposed of it January 1, 1897, to its present owners, the Mountain Copper Co. (Limited) of London, an English corporation, with a capital of $6,750,000. The latter company, at the same time, acquired the New Jersey Metal Refining Works, Elizabeth, N. J.

"The mine is situated about twelve miles northwest of Redding, in a mountain spur, about 7,000 feet wide, formed by Boulder Creek on the north and Slick Rock Creek on the south, both tributaries of Spring Creek, which flows southeasterly into the Sacramento River. The altitude of the creeks at the mine is about 2,300 feet, and of the summit of the dividing ridge 3,300 feet. The most pronounced ore-cropping is at the southerly end at Slick Rock Creek, where an immense mass of oxidized ore, commonly called gossan, 300 feet wide, traverses northeasterly the mountain slope to the summit of the ridge. From this point northeasterly to Boulder Creek the croppings branch out into two or three undulating belts, each nowhere exceeding 100 feet in width.

"It is a peculiar fact that the best copper sulphide ores are not always found under the biggest gossan croppings. Very often no sulphides have been found for a length of 300 feet—as shown by the Peck Tunnel, of this property—under the richest and most inviting surface croppings; and, frequently, big masses of sulphides are found underlying porphyry, with no indication whatever of surface mineral. The main ore bodies of this property are lenticular-shaped masses, composed of gossan ores on the top, with the heavy, unaltered sulphides underneath, the division between the two classes of ore being well defined; the gossan ores rarely going beyond a depth of 125

[3] O'Shaughnessy, M. M., The copper resources of California: California Miners' Assoc., California Mines and Minerals, pp. 206-211, 1899.

feet from the surface. There is no doubt but, originally, they were the same composition as the sulphides, but the leaching process, continued for years, has abstracted all the copper contents, and left them proportionately richer in the precious metals. They will average $1 in gold, $3 in silver per ton, with practically no copper, while the sulphide ores, varying from one and one-half percent to twenty-one percent, with an average of seven and one-half percent copper, carry only $0.70 in gold, with $1.50 in silver value per ton. A longitudinal section of the country over the outcrop, showing the explored masses in heavy lines, would be as follows:

"The mass marked 'A' on plan, near the southwestern extremity of the ore body, is the present source of ore supply for the smelters. It is, roughly speaking, 800 feet long, 300 feet wide, varying in depth from 100 to 300 feet at its lowest point. The walls at the bottom converge, so as to make it wedge-shaped in section, and of about 1,700,000 tons in extent. The property was marketed on proof of this mass alone; since then, exploration work has been prosecuted with the diamond drill, demonstrating the existence of a large low-grade mass 'B' at the Hornet, or Boulder Creek end, while recent work shows a marked improvement with depth in the grade of this ore.

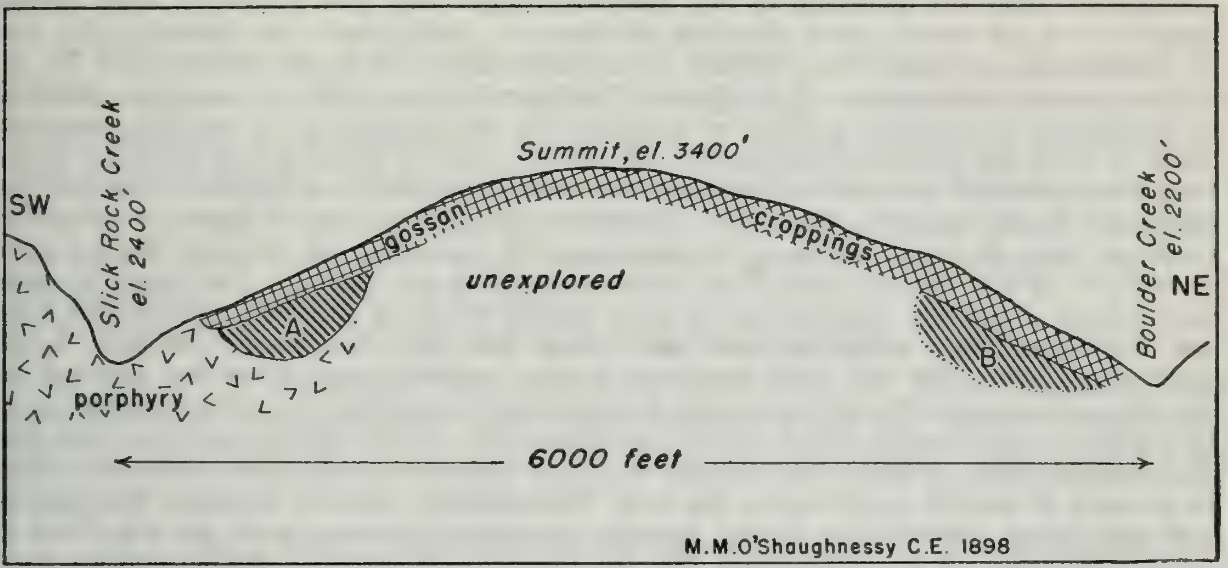


FIGURE 1. Longitudinal section, Mountain copper mine, Shasta County

"The three problems of greatest interest to the engineer, in connection with the development of a new property, are (1) The mining, or extraction, of the ore; (2) the transportation; (3) the reduction. This property furnished a new and interesting field for the efforts of the specialist in each line. Mr. Alexander Hill introduced a very simple method for extracting the ore by replacing quarry rock from the surface of the adjacent ground, in the cavities formed by the extracted ore, thus reducing the cost of timbering to a minimum; and making the extraction of such large masses of ore absolutely safe, in preventing any caves in the surface ground. The writer of this article was employed as engineer on the transportation problem, and had to meet the following conditions:

(a) To design a system for transporting 1,000 tons of ore per day, from an altitude at the mine of 2,300 feet to one of 600 feet at the smelter site, now Keswick, at Spring Creek, about one mile west from the Sacramento River.

(b) To do so at a minimum of cost, and in the shortest time consistent with good work.

(c) To keep in mind facilities for calcining the ore, procuring fuel, and such other contingencies as might arise in the development of a property of such magnitude.

"To anyone acquainted with the topography of this portion of Shasta County—whose surface is exceedingly steep—the inability to procure only five or six acres of a level site for a smelter will be at once apparent. Such a spot was to be had only at Keswick, the site of the present smelters, with an altitude of 620 feet. It presented the additional advantage of a good supply of water, and abundant dumping ground for slag from the furnaces, without interfering with any vested rights in the adjacent lands or streams. I decided that a three-foot gauge railway would best fit the conditions by laying an additional rail, for a mile and a quarter, from Keswick to the main line of the California and Oregon Railway, so that the broad-gauge freight cars could be hauled up to the smelter yards, and unloaded without transshipment. After many preliminary investigations of the intervening ground, which was very rough, I determined on a maximum grade of 200 feet to the mile, and to use as the sharpest curve a 34°,

or one of 169.13 feet radius. Construction work on the railway was commenced in August, 1895, and the line was opened for traffic February, 1896. In order to keep within the maximum gradient, it was necessary to build one loop around Tin Can Point, which adds to the scenic attractions of the line. Between reverse curves, sixty feet of tangent was always introduced, and on all curves the grades were lightened to compensate for curvature. At the mine end, the line terminates in a tunnel, from which upraises have been made to the ore bunkers overhead to facilitate the loading of the ore cars. At the Keswick end, the cars dump from a trestle elevated about twenty feet above the surface of the smelter yard. The locomotives used on the road have a short wheel-base, and were designed and constructed by H. K. Porter & Co., of Pittsburgh. The smoke from the smelters and burning roast-heaps has a tendency to lubricate the rails and cause slipping of the wheels, and this has been overcome by using the sand-box freely; and, although the curves are sharp and the gradients steep, the road has been singularly free from accidents, having yet to record its first fatality.

"The method of reducing the ore caused the management of the Company much worry and expense before a practical system was adopted. The pyritic process was first attempted under the direction of Mr. Herbert Lang—who has written a book on the subject—but the results were far from satisfactory, and caused the Company the loss of considerable valuable time, before it was abandoned as impracticable. Mr. H. A. Keller, then superintendent of the Parrot Smelting Works, at Butte, was next retained to inaugurate a practical method of smelting the ore. He did so by building roasting stalls to burn the excess of sulphur out of the ore, and by erecting two ordinary Montana blast furnaces to smelt the reduced ore, with the addition of silicious ores and the necessary fluxes and coke. The plant at the present time consists of three water-jacket furnaces, each 42 x 150 inches at the tuyeres, with a distance of nine feet from center of tuyeres to the charge floor. They are charged, on an average, 160 times in each twelve-hour shift, the composition of each charge being as follows: roasted sulphide ore, 1,300 lbs.; raw sulphides, 400 lbs.; silica 400 lbs.; limestone, 100 lbs.; total, 2,200 lbs.; coke, 170 lbs. The resulting copper mattes carry forty-five percent to fifty percent copper. The fluid slag was first shotted in running water and carried away in a flume to the dump; owing to the low altitude at which the furnaces were placed, the available area of dump was quickly filled, so that now mechanical appliances have to be used to elevate and remove the slag. The capacity of each of those furnaces is 200 tons every twenty-four hours. Special calcining furnaces, built by the Park & Lacey Company, of San Francisco, for the smelting of the fines, have recently been built and have a capacity of about 250 tons per day.

"Several tiers of roasting kilns were constructed of heavy masonry, six feet deep, seven feet wide, and fourteen feet long, with side and end drafts, each capable of holding a thirty-five-ton charge, and all connected with a big smoke-stack leading up the side of the mountain to carry away the sulphur fumes. The concentration of the smoke from all those kilns proved so annoying to the workmen, that a simpler process is now in practice of burning the ores in various heaps, distributed at isolated and suitable points along the railroad toward the mine. The ore is received in bunkers from the mine cars, and piled around flues made of wood, on the natural ground. After the piles are properly shaped, and proper precautions taken for providing a suitable draft, the wood is ignited and the piles slowly burn for sixty days, when the ore, less the excess of sulphur, is again loaded on the railway cars and conveyed to the smelter.

"This system is much cheaper than the kiln burning, as the great heat of the burning ores in the latter causes breaking and distortion, which involve a constant expense in repairing them. It is also more agreeable to the laborers, as the isolation of the heaps keeps the smoke nuisance down to a minimum.

"The necessary power for supplying the smelting plant is furnished by water pressure in the winter time, and by steam from wood in the summer season, when the water runs short. The phenomenal drought of 1898 caused the erection of a pumping plant in the Sacramento River, near Spring Creek railroad bridge, which forces 2,000,000 gallons daily, against a head of 150 feet, through eighteen-inch and sixteen-inch pipe to the smelting site. As the Sacramento River fluctuates in height as much as thirty feet, a portable railway has been provided to pull the pumps out of the river bed in the flood seasons, when the water from this source is unnecessary.

"During the year 1898, the quantity of ore taken out of the mine was 221,895 tons, averaging 8.42 percent copper, or 740 tons per working day, against 165,060 tons, averaging 8.56 percent copper, or 550 tons per day, in 1897; an increase of 56,835 tons, or 190 tons per day.

"The quantity of ore smelted was 168,541 tons, producing 10,721 tons of copper, against 97,185 tons, producing 7,238 tons, in 1897. The quantity of finished copper marketed was 8,273 tons, against 6,025 tons, in 1897, an increase of 2,248 tons. The

net profits, after deducting all costs and charges, amount to $815,000, against $315,000 in 1897. Seven and one-half percent dividends, amounting to $468,750, were paid out of the profits, and the balance of $346,250 was placed to the credit of the reserve and depreciation fund. This would show a profit of $4.84 on each ton of ore smelted during 1898, when the price of copper was normal. With the splendid waterpower available for refining the copper by the electrolytic process at Keswick, there is no reason why the profits could not be increased fifty percent by producing fine copper at Keswick, and save the freight of $15 per ton on the sulphur in the matte now shipped to New Jersey, and the added extra expense of treating it at separate establishments there.

"The starting of the Keswick smelters has proved of great advantage to the miners of Shasta County, who are able to dispose of their ores from the numerous quartz veins traversing the district, and have them smelted at a moderate cost. The silica of these ores is necessary for a flux, owing to the lack of this mineral in the Iron Mountain sulphide ores. The Company has never favored the policy of procuring its own quartz for this purpose, preferring to see the individual enterprise of the small mine-owners encouraged, rather than attempt to make developments in this field."

Calcining in 1896 was done in roasting kilns, as described by O'Shaughnessy. These were built of comomn country rock, and were held together with lime and cement mortar. In practice they did not prove very satisfactory; for in some of the kilns the fires seemed to get a poor start, and could not be refired, while in other kilns they would do well—in fact too well, because they would fuse a solid mass which could not be extracted, not even by blasting.

After two or three fillings, these stone kilns or "stalls" were abandoned in favor of open-air heap roasting, in which blasting was permissible. Occasionally there would be as much as 350,000 tons burning at one time. There was one bedding ground which contained 90,000 tons, all roasted as one operation.

In firing these heaps, 4-foot cordwood was used. These sticks were placed on the ground, before the ore was dumped, in such a manner that vents would be left carrying across under the piles; chimneys were made of cordwood and carefully spaced to prevent any possibility of incomplete firing. For the first 10 days after lighting the heaps gave off huge volumes of sulphur-dioxide gas that was most disagreeable.

Only coarse ore (larger than a walnut) was used in building the heaps, and previous to the erection of eight Wright-McDougal roasters, the fines were stored where they could be recovered later. Ultimately, the fines were roasted and the product put through a briquetting machine. Also, crude fines were briquetted before being charged to the blast furnaces, particularly after pyritic smelting was adopted, when less calcines were required and the necessity for heap roasting was much reduced.

In 1898-99 The Mountain Copper Company acquired timberland aggregating 2,680 acres in the Big Bend section on the flat, wooded banks of Pit River, some 65 miles northeast of Keswick, for the purpose of supplying cordwood fuel for steam boilers, railway locomotives, and ore-heap roasting at Keswick, and to obtain mine timbers and lagging for mining operations at Iron Mountain.

All of these materials were cut in the spring and early summer so that they would be partly dried before being floated down the river to Keswick. The drive was started some time in September so that it would be completed before the fall rains set in. After all the timbers and wood had been delivered into the river, it took 15 men 25 to 30 days to follow the drive and to dislodge the timber and wood suspended in shallow water or in recess pools along the 65-mile course. In some cases, a

complete jam would be found. At the delivery point at Keswick, a sheering boom was placed across the river to a receiving pond, where a chain conveyor belt carried the material to a loading platform alongside the railway track. This means of obtaining cordwood and timber was discontinued in 1901, when crude oil became available for use in all steam plants and locomotives. Also, by this time the cordwood requirements for heap roasting were greatly reduced, and mining timbers and lagging were obtained from Oregon.

No figures are available to show the total amount of wood and timber delivered during the 3 years that this system was in operation; but it is recalled that in one of these years a total of 34,000 cords of 4-foot wood was delivered. Some of the larger mining timbers that were not too well seasoned did sink in the river and could not be recovered.

All the work on this Pit River wood and timber project was contracted to the firm of Buick & Wengler; both men were reliable and faithful to the end.

From O'Shaughnessy's brief mention of the mining system introduced by Alexander Hill, the inference might be made that it was ideal. Such was not the case, however, for certain sections of the mine caught fire in 1898. The cause was undoubtedly spontaneous combustion in the mine. When mining operations began, the system of extracting was that of slice-stoping; that is, starting at a certain floor level, the ore was taken out to a height of 7 feet, clear across the sulphide mass, and heavy upright posts were put in, where the roof looked dangerous. When a certain area had been opened, the void was filled with common surface rock shot down through an uprise from the surface of the mountain. It was always within these fillings that the fires started, generally after a section had been sealed off and was out of reach.

The first effort made to combat these fires was with water through cracks from the surface. This water, obtained from the gulch above the camp, was not enough, so a large pump was installed on Boulder Creek and a 6-inch pipe laid around the mountain. Thus a great quantity of water was made available, but it was quite out of the question to get it where it would affect the fire. Truly, some water did get on the fire, and came out of the tunnels quite coppery and warm, but of course no one could get underground on account of the gases.

When water failed to do the trick, another method was tried; namely, a large fan, made of sheet iron, was installed on one side close to the portal of the tunnel, and everything about the mouth of the tunnel was sealed, entrance being through a padded door. This fan was 36 or 40 inches in diameter, had 30-inch blades, and was run at 350 revolutions per minute. It was encased in riveted sheet iron and the entrance for the air was a mouth-shaped bell; from the bell air was conveyed to any desired part of the mine through a 6-inch pipe. This arrangement did little toward putting out the fire, but it greatly reduced the temperature and held the gases back, enabling the men to get inside the workings where they could fight the fires at the face with water, and in due time extract the ore. It was a very warm process, but a great deal of high-grade ore was recovered in this manner. Men sometimes had to work in relays and, in case the power went off, they had to retreat to the surface at once; often the gas beat them to the mouth of the tunnel. In the begin-

ning, this seemed to be the only method of fire control applicable to the conditions at Iron Mountain.[4]

Subsequently, in 1905, J. J. Shaw, who had been in charge of the underground work at Iron Mountain, applied the same system quite successfully to control underground fires at the United Verde mine in Arizona.

After Herbert Lang's unsuccessful attempts at pyritic smelting at Keswick, the usual blast-furnace practice was followed, as introduced by Herman Keller; but about the time L. T. Wright arrived from London, in the late spring of 1897, to become general manager at Keswick and relieve the then general manager, Alex Hill, a great deal of interest was manifest regarding the successful pyritic smelting practice as developed at Mount Lyell, Tasmania. Wright and the London office also became interested, and shortly thereafter George F. Beardsley, who was then or formerly had been connected with the operations at Mount Lyell plant, arrived at Keswick and stayed 2 or 3 weeks in a consulting capacity. At a later date, J. W. Bennie, smelter superintendent, was sent to Mount Lyell where he obtained data, blueprints, etc., and a start was made at Keswick towards the installation of equipment for pyritic smelting. This equipment included a pre-heating air-blast system. A large brick-walled compartment was built about 35 feet long by 12 feet wide by 10 feet high, with brick arch roof and heavy I-beams across from side-wall to side-wall. These beams supported a series of 10-inch cast-iron U-pipes connected on the outside to pipes carrying compressed air from the Connersville blowers, installed in the powerhouse nearby. Oil was used to heat these pipes thus suspended in the heating chamber; temperature of the blast at the stoves was 750 degrees Fahrenheit, and 400 to 425 degrees at the blast furnaces.

Beardsley was not altogether successful during his visit in operating the furnaces on a pyritic basis, partly because he was compelled to use a very refractory flux which was none other than the local porphyry, and had a very high $Al_2 0_3$ content.

A. S. Haskell became smelter superintendent in 1902 and remained in that position until 1904, when he was transferred to the Martinez plant. He reports that, after Beardsley's departure, further experiments were conducted with pyritic smelting, but that the fluxing was with a highly siliceous ore from Quartz Hill, and that the results were quite satisfactory on short runs. He adds that the difficulty of smelting the Iron Mountain sulphide without coke was due mainly to the large percentage of zinc and partly to the furnace construction. The blast furnaces had brick tops which were continally being choked with molten flue dust, to such an extent that at times the escape of smelter fumes into the stack was actually cut off. Later, at the Mammoth smelter near Kennett, which worked with similar furnaces with brick tops, this difficulty with flue dust was entirely overcome by replacing the brick tops with water jackets.

Ultimately, when it had been determined that the chief factor contributing to the success of the pyritic smelting was the pre-heated air blast, this method was employed to a considerable extent at Keswick. Before the hot-blast stove was installed, cold blast was tried, but the

[4] For a more detailed description of this method of fire control, see Wright, Lewis T., Controlling and extinguishing fires in pyritous mines: Eng. and Min. Jour., vol. 81, pp. 171-172, 1906.

Run of No. 4 blast furnace May 31st to June 9, 1904

Blast on 7:30 P.M. May 31st; blast off June 10th 2:30 A.M.

Date 1904			Total burden		Crude ore equivalent		Coke			Blast		Fuel oil	Assays			Cost c per ton total burden				Cost c per ton crude ore equivalent			
													Matte	Slag									
		Hours run	Tons, net weights	Tons per hour	Tons, net weights	Tons per hour	Tons	Percent of T.B.	Percent of C.O.E.	Pressure, ozs.	Temp., degrees F.	Gallons	Cu, percent	Cu, percent	SiO₂, percent	Labor	Coke	Fuel oil	Total	Labor	Coke	Fuel oil	Total
May	31	10½	180.2	17.2	129.7	12.4	2.988	1.7	2.0	24	418	828	23	.58	31.5	27.8	20.4	9.3	57.5	38.6	24.0	12.9	75.5
June	1	24	397.2	16.5	282	11.7	----	----	----	30	417	1,110	30.8	.68	30.7	29.0	----	5.9	34.9	40.9	----	8.3	49.2
June	2	24	414.0	17.2	295.4	12.3	----	----	----	29	410	1,165	28.6	.66	30.2	27.8	----	5.9	33.7	38.9	----	8.3	47.2
June	3	24	397.9	16.6	289.5	12.1	----	----	----	30.1	410	1,160	32.2	.64	31.5	28.8	----	6.1	34.9	39.6	----	8.4	48.0
June	4	24	365.8	15.2	261	10.9	----	----	----	29.2	410	1,108	30.3	----	----	31.6	----	6.4	38.0	44.0	----	8.9	52.9
June	5	24	353.8	14.7	250.5	10.4	----	----	----	30.1	410	1,102	32.1	.58	33.2	32.6	----	6.5	39.1	46.0	----	9.2	55.2
June	6	24	329.4	13.6	235.5	9.8	----	----	----	30.4	395	1,068	26.8	.56	33.1	35.0	----	6.8	41.8	49.0	----	9.5	58.5
June	7	24	406.2	16.9	289.5	12.1	----	----	----	36.6	350	918	30.7	.51	32.6	28.3	----	4.7	33.0	39.6	----	6.7	46.3
June	8	24	389.9	16.2	282	11.7	----	----	----	37.7	272	742	33.1	.59	32.6	29.6	----	4.0	33.6	40.9	----	5.5	46.4
June	9	20½	296.8	14.5	213.8	10.4	----	----	----	37.0	220 atmos.	224	30.3	.53	30.8	33.0	----	1.6	34.6	46.0	----	2.2	48.2
Totals and averages	----	223	3,531.2	15.8	2,528.9	11.3	2.988	.08	.12	31.4	360	9,425	29.8	.59	31.8	30.4	1.0	5.6	37.0	42.3	1.4	7.8	51.5

Ordinarily the blast pressure maintained on the Keswick smelter furnaces was around 28 ounces, but there was one run as detailed above on No. 4 furnace from May 31st to June 9, 1904, when on June 7th the blast pressure was raised to 36 ounces. The furnace had been running slow at six charges per hour. The effect of the increased blast became evident at once by the increase in speed of the furnace, which began to run sc fast that the temperature of the blast was lowered gradually and, as the furnace continued to run well without seeming to be materially affected by the lowering temperature, the hot blast stove was cut out at 2.30 p.m. on June 9th, after which the furnace ran well until midnight when, without warning, the charge hung up in the upper part of the shaft and about 2.30 a.m. on June 10th the furnace had to be tapped out. Mr. Haskell has expressed the opinion that the stoppage of this furnace was due mainly to an excess of zinc in the storage ore which came down that day, and this idea is supported by the fact that both No. 2 and No. 3 furnaces were nearly lost next morning from hanging up, when the supply of mine ore became low and they were only saved by much muscle and coke.

"freezes" came too often, necessitating the digging out of the furnace shafts. As soon as the hot blast was available, however, some remarkable records were made. For instance, one run of 96 hours was made without an ounce of carbonaceous fuel; but after considerable practice it was found that better results were obtained by using some coke on every charge, plus some extra coke whenever the slag became sluggish. Likewise, the use of the correct proportion of limestone was important.

Haskell was very meticulous in recording details of smelting practice at Keswick, and his personal notebook contains a fund of valuable metallurgical information obtained during the period 1902-04. The tabulation presented herewith of one particular run on No. 4 blast furnace from May 31 to June 9, 1904 serves to illustrate the kind of data he compiled and preserved.

NO. 8 MINE AND THE MINNESOTA MILL

By 1907 it became evident that the high-grade copper ore in the original Iron Mountain ore body was nearing exhaustion. For several years previous there had been in progress a continuous and extensive program of diamond drilling, undertaken in the hope of discovering further occurrences of high-grade sulphide ore below the enormous outcrop of gossan; but, except in some isolated instances, the diamond-drill holes penetrated the gossan without encountering massive sulphide. Occasionally there would be a core from one of these holes that consisted of siliceous gangue showing traces of disseminated pyrite and some chalcopyrite, but since this was not the type ore being sought, it was regarded as of no particular significance. In 1907, however, when one of these cores indicated more than 30 feet of what T. J. Jones, mine superintendent, thought might be a siliceous copper ore, an assay was made. It showed an average copper content of about 3 percent, whereupon other cores of similar character, previously deposited in the core boxes, were examined and assayed, with the result that it became reasonably certain there existed at a horizon relatively lower than the original high-grade sulphide ore body, a commercial deposit of siliceous chalcopyrite ore. Development confirmed the existence of this ore body, and ultimately it was opened extensively. Besides an adit, driven about 2,400 feet above sea-level, a three-compartment incline shaft was sunk and three lower levels were established, known as the 160, 280, and 400. Subsequently, ore of similar character was discovered at a higher elevation in what was called the "Complex vein". Altogether, the No. 8 mine produced close to a million tons of pay ore and was not exhausted when the price of copper declined to a point where the operation became unprofitable.

During the early development of the siliceous copper ore body, the management became quite optimistic as to the outcome, and the directors in London decided to send a well-known mining engineer from New York to make an independent report. Upon arriving in San Francisco this engineer remarked, "Well, I have come to prepare the No. 8 mine for burial". Subsequently, before completing his report, he asked what quantity of ore was "in sight", and was told at least 50,000 tons. As the ore was not "blocked out", he wanted to know the basis for the calculation. He was told that more than 10,000 tons had been shipped to the smelter at Martinez, all taken from drifting and cross-cutting, and that it was a practical certainty there was not less than five times that tonnage which could be extracted from that same area. He included the 50,000 figure in

his report, intimating it was a guess by the management, but the result was that no further attempt was made to inter the alleged corpse.

Siliceous ore was very much needed as a flux in the Martinez smelter. Beginning in 1909 regular shipments of No. 8 ore were made, which carried about 5 percent copper. To maintain this grade, it was necessary to do "selective mining", or, as a Cornishman would express it, "to pick the eyes out of the mine".

During the development of the No. 8 mine, several high-grade ore bodies were encountered, and being under the erroneous impression that the superintendent was a devout Catholic, the manager adopted the Latin-American custom of naming each of these after a Saint. The first was found on the 17th of March, and was dubbed "Saint Patrick"; but the next was nameless until it was fairly well opened up, when, after consulting an almanac, it was decided that "Saint Bartholomew" was an appropriate name. Some months later the superintendent wrote about some especially rich ore that was showing up in the "Liberty Bond" ore body, and, when the manager tactfully suggested it was his prerogative to name the new discoveries, the superintendent's somewhat brusque and profane reply was that he was fed up with those "damned Saints" and wanted no more of them.

In 1913 the firm of Burch, Caetani & Hershey was appointed as consulting engineers, and shortly thereafter, on their recommendation, the erection of a mill for treating the No. 8 ore was undertaken. This plant consisted of two portions, one near the portal of the No. 8 mine where the preliminary crushing was done and the ore reduced to about $\frac{3}{4}$-inch size, and the other at Minnesota, a point on the Iron Mountain Railway about half way between Iron Mountain and Keswick.

The "Minnesota mill", as it was called, was designed by the late Gelasio Caetani during the early part of 1914 and construction was carried on until the outbreak of World War I in August of that year. At that time the mill was about 85 percent completed, but all construction work was stopped until March 1915, when the plant was finished according to the original plans. In the meantime Caetani had gone to Italy where he was a captain in the Engineering Corps of the Italian Army from 1914-19, after which he was appointed ambassador to the United States by Mussolini, serving 2 years at Washington, D.C. He then returned to Italy and took a prominent part in the engineering connected with reclaiming the Pontine marshes, one of Mussolini's pet projects for increasing the agricultural land area for the benefit of the peasants.

The mill as designed by Caetani was the first in California to use flotation. Its flow-sheet is described in the following paragraphs.

The $\frac{3}{4}$-inch chalcopyrite ore from Iron Mountain, which contained an average of about 2 percent copper, was transported over the Iron Mountain Railway to the mill, where it was weighed on track scales and dumped into the receiving bunkers for subsequent treatment. From the bunkers the ore passed through two sets of 16- by 36-inch rolls, in closed circuit with trommels fitted with a screen having openings 12 by 26 millimeters. The undersize from the trommels was treated in an 18-foot Hancock jig, from which the first three hutches gave a product carrying 7 to 8 percent copper that was deposited for draining in flat-bottomed bins provided with coconut matting and canvas filters. The drained concentrates were shipped to the company's smelter at Martinez. The tailings from the

Hancock jig were dewatered and ground in two 18-foot by 36-inch Hardinge pebble mills working in closed circuit with chain-drag classifiers. The minus 60-mesh product went to a gear-driven 18-inch 10-cell mineral separation flotation machine with a daily capacity of 200 to 250 tons.

The excess water from the Hancock jig and from the dewatered slimes was carried to a 32- by 10-foot Dorr thickener, the underflow from which went to no. 1 cell of the flotation machine, while the overflow water from the thickener was pumped back for use in the Hancock jig. The flotation concentrates assayed from 12 to 18 percent copper, and the tailings from 0.15 to 0.25 percent copper.

The flotation reagents used in the early days on this type of ore consisted of cresylic acid, pine oil, kerosene acid sludge, tar oil, crude turpentine, and stove oil. These reagents made such a persistent and tough froth that the mill pumps had difficulty in handling it. The original plan was to pump this froth into the same filter bins that were used for the product of the Hancock jig; that is, the froth was to be mixed with the coarser jig concentrate, with the idea that the combined mass would drain to a ''shipping dryness''. A water suction was provided below the filter bottoms of the bins to facilitate the draining. However, this filtering scheme for the flotation concentrates was not a success, because the pumps were able to deliver only a part of the flotation froth to the drainage bin, and that part which reached the bin would not drain sufficiently.

During the trial runs of the mill in April 1915, it immediately became evident that a mechanical filter would have to be substituted in order to obtain a flotation concentrate that was dry enough to ship. A bucket-elevator was installed to replace the pumps for handling the flotation froth, but the filter bins still were used for draining the coarse concentrates from the Hancock jig.

During this period copper was selling at 24 cents per pound, and it was important to solve at once the problem of how to obtain a flotation concentrate that was dry enough to ship. In short, there was no time for making careful tests, and an order was placed for prompt delivery of a Dorr thickener and an Oliver filter. This installation cost approximately $25,000, but after it had been made the mill operated continuously and satisfactorily until March 1917, when it was shut down so that the rolls, trommels, and Hancock jig could be replaced with two 7- by 6-foot Allis Chalmers ball granulators. These were promptly installed in open circuit with Simplex Door classifiers. The overflow from the Dorr classifiers went directly to the No. 1 cell of a new 24-inch 16-cell 500- to 600-ton minerals separation flotation machine, which replaced the old 18-inch 10-cell machine. The oversize from the Dorr classifiers went to the two original Hardinge pebble mills.

With the above additions, the mill became an ''all flotation'' plant with a capacity of 550 to 600 tons per day. The enlarged and remodeled mill operated steadily from May 1917, to March 5, 1919, when it was shut down on account of the low price of copper.

The site selected for the Minnesota mill was adjacent to Spring Creek, and the mill utilized water from that source. An adjoining flat area was available for tailings disposal, and, since the Iron Mountain Railway was not fully employed at that time in transporting Hornet pyrites to Keswick, it seemed logical to haul the ore to the mill rather

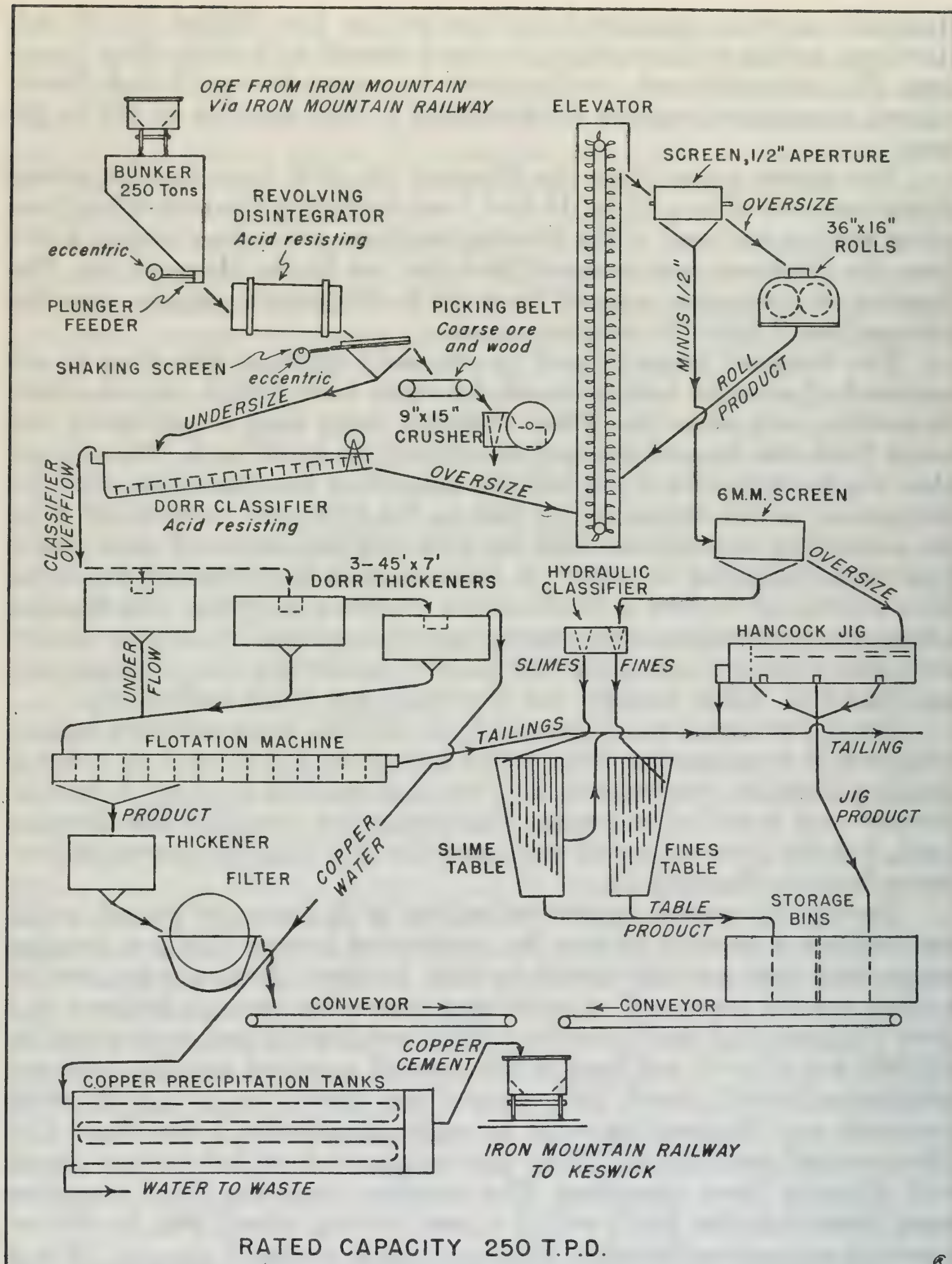


FIGURE 2. Old mine filling treatment plant at Minnesota Station

than to erect the mill at Iron Mountain and pump the water uphill to the mine. Later, in 1928, when the narrow-gauge railway was no longer in operation, and the price of copper justified the re-erection of the flotation mill at a site a short distance below the portal of the No. 8 mine, it was obvious that the economical thing to do was to pump the Spring Creek water up to Iron Mountain. Accordingly a 6-inch pipeline was installed with a pumping plant at the lower end. The problem of tailings disposal from the re-erected flotation mill was never satisfactorily solved. Tailings dams were built in Slick Rock Creek, but they proved to be a

constant source of trouble and resulted in a series of complaints from the California Fish and Game Commission.

Re-erection of the Minnesota mill at Iron Mountain was started in the autumn of 1928 and completed early in April 1929. It continued in operation for a little over a year, when the price of copper, which had been pegged at 18 cents, suddenly slumped to 14 cents and kept right on going down, until in 1933 it reached a low of 5 cents. Subsequently the price gradually increased but it was not until 1941 that it seemed more or less established at 12 cents. Even at this figure the No. 8 mine could not operate at a profit, and by the time the United States entered World War II, the underground workings had deteriorated to a point where their reopening was practically impossible.

Re-opening of No. 8 mine, re-erection of the mill, and rehabilitation of the camp at Iron Mountain cost in round figures about $100,000, resulting in a loss, all due to the uncertainties of the copper market.

OLD MINE FILLING

The top-slicing method of mining and filling, originally adopted at Iron Mountain, with the subsequent calcining from underground fires, resulted in large areas of a mixture of broken surface rock with sulphide fines and calcines.

This filling occupied much of the space of the original ore body, but, in the course of time, a large portion of its soluble copper was leached out and it was compressed, by the weight of the over-burden, into a mass variously estimated to contain from 150,000 to 500,000 tons, carrying perhaps 2 percent copper and a nominal amount of gold and silver.

In the latter part of 1911 a study was made to determine the feasibility of extracting and treating this ''old mine filling'' at a profit. Tests were not encouraging and the matter was allowed to rest until 1917, when the United States entered World War I and there was an unprecedented demand for copper, so that the price advanced to a very profitable figure.

By this time Caetani had severed his connection with the firm of Burch, Caetani & Hershey, consulting engineers for the company, but Burch obtained the services of a competent metallurgist, R. W. French, to make tests and to recommend the proper method of treatment. The samples used in the tests made by French averaged about 1.60 percent copper (0.35 percent of which was soluble), 0.03 ounces of gold and 0.80 ounces of silver. French recommended the flowsheet used in building the No. 2 mill at Minnesota Station, which is similar to that shown in figure 2. L. C. White, then mill superintendent, designed and superintended the construction work, which began in 1917. Because of the labor shortage during World War I, however, the plant was not completed until early in 1919. It was then operated intermittently for short periods, until a sudden radical drop in the price of copper compelled suspension of the work.

The mill was operated long enough, however, to indicate many defects, both mechanical and metallurgical. These included the certainty that the thickener slimes could not be combined with the No. 8 sulphide ore and treated by flotation in the No. 1 mill; and it became evident that, even under the best conditions, a marketable concentrate could not be produced by flotation from these slimes. Furthermore, the filling was

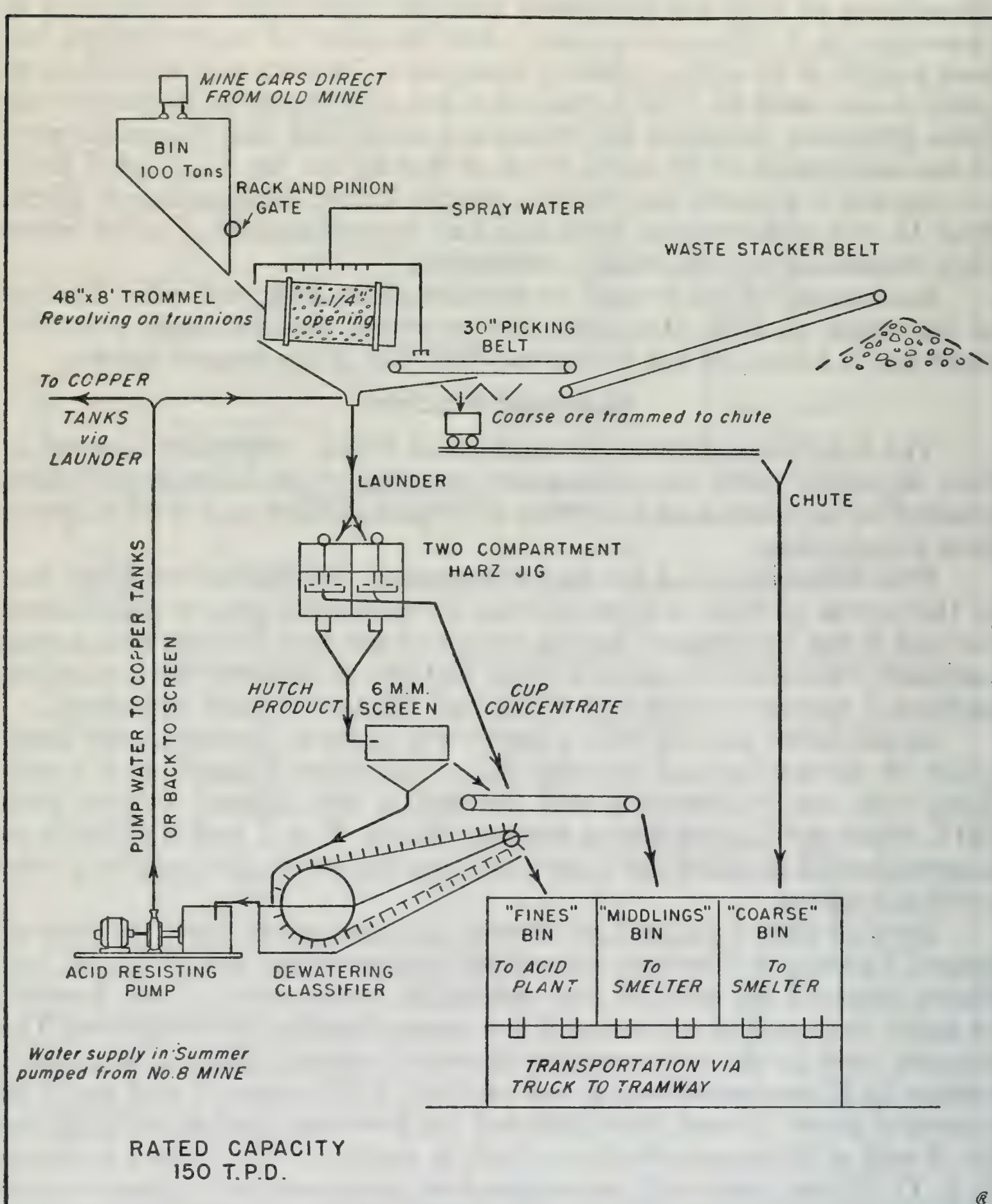


FIGURE 3. Old mine filling plant at Iron Mountain

found to contain a considerable quantity of wood from the old stope timbers, which proved a source of constant trouble.

In 1925, some changes were made in the mill and it was again operated for a few weeks to determine if, under the economic conditions then existing, it would be profitable. It soon developed that the necessary changes and additions were not justified, and also that the copper cement produced from the thickener slimes (slimes were principally calcines) was too low grade to justify shipment to the smelter, even when beneficiated by tabling. Unfortunately, such slimes constituted a large portion of the old mine filling.

In 1929, a second and much simpler plant was erected at Iron Mountain, on a level convenient for tramming the filling direct from the mine to the mill, whereby the cost of transportation was much reduced. The flowsheet of this second installation is shown in figure 3.

This plant functioned successfully, both mechanically and metallurgically, but production from the mine was low and erratic and early in 1930 the operation was discontinued. At that time the remnants of good-grade sulphide ore in the old mine ceased to yield a sufficient tonnage to justify the operating costs, and it was generally agreed that there was no possible profit in continuing the effort to mine, mill, and market the old mine filling alone.

DECLINE OF KESWICK

Shortly after the turn of the century, consideration was given by the management to the utilization of the sulphur contained in the Iron Mountain ore and, coincident with this idea, the Pacific Coast Oil Company (predecessor of the present Standard Oil Company of California) expressed an interest in securing a regular supply of sulphide ore to be used in its Richmond refinery for the production of sulphuric acid. The result was a contract for the supply of 1,000 tons per month, which was sold on the basis of roasting off the sulphur and returning the residues or calcines to The Mountain Copper Company for the extraction of the copper, gold, and silver. The necessity for smelting these calcines, plus the evident possibilities of the acid business in the San Francisco Bay area, led to the purchase of an 80-acre tract on Suisun Bay, near Martinez, and the erection of a complete copper smelter, including an acid plant and a factory for manufacturing commercial fertilizers.

A considerable portion of the Keswick smelter was removed to Martinez, but several of the blast furnaces were retained and in 1907 these were utilized for the production of copper matte, which was shipped to Martinez, remelted in the reverberatory furnaces and converted into blister copper for transportation to Baltimore, where it was refined by the electrolytic method. All smelting at Keswick had ceased by the end of 1907, but for several years thereafter, Keswick was maintained as the railway terminal for the shipment of crude ores and the receipt of various supplies.

Likewise, the very complete shops and foundry continued to operate, keeping equipment for the narrow-gauge railway in good condition, and making necessary repairs for the mine.

It was not until after the suspension of operations on the narrow-gauge railroad in 1921 that the machine shop was removed to a point on Boulder Creek, convenient to both Iron Mountain and the Hornet mine.

This ended all activities at Keswick, which soon became little better than a "ghost-town", and so remained for many years.

Besides the principal mines at Iron Mountain, the company acquired various other mineral locations in the same neighborhood. These included the Hornet mine, which subsequent development proved to contain a considerable tonnage of pyrites averaging about 50 percent sulphur. This high-grade pyrite is an excellent source of sulphur for the manufacture of sulphuric acid, and shipments of this ore started to the San Francisco Bay area in 1907 and have been continued steadily ever since.

Prior to 1907 a considerable tonnage of Iron Mountain ore was used in the vicinity of San Francisco for producing sulphuric acid of about 94 percent strength, which was largely used for oil refining. It soon developed that a stronger acid was more efficient; this resulted in a demand for a high-grade pyrite and necessitated the substitution by the acid plants of the contact process for the chamber process.

Originally, the manufacturers of both weak and strong acid utilized lump pyrite, $1\frac{1}{2}$ to 2 inches in size, for producing sulphur-dioxide gas. As previously stated, this lump material was supplied first from the Iron Mountain mine, but beginning in 1907, it came from the Hornet mine. Production of these "lumps" involved screening out the fines resulting from the crushing and screening of the massive ore; these fines were put into storage near Boulder Creek until thousands of tons had accumulated.

However, in the summer of 1920 the use of lumps was abandoned and pyrites fines took their place. This resulted in the prompt sale of the accumulated pile of fines, and at the same time made it necessary to install heavier crushing equipment with ample screening capacity.

An entirely new crushing and screening plant was constructed and this was completed and put into operation during October 1920. At that time transportation was still over the narrow-gauge railway to Keswick. This new crushing and screening plant represented a very heavy capital expenditure.

Besides a No. 6-K gyratory crusher for handling the coarse mine run, two sets of Traylor AA rolls, 42-inch diameter by 16-inch face, were provided, together with suitable trommels and conveyors. These rolls weighed 62,100 pounds each, one set doing the coarse crushing and the other finishing to minus $\frac{3}{8}$-inch size. This combination proved very effective, although at a later date Hummer screens were substituted for the trommels.

The only site available for the upper terminal of the aerial tramway was in the narrow canyon of Boulder Creek; it necessitated utilizing certain bunkers which had served for loading the narrow-gauge railway cars carrying the Hornet ore to Keswick. At Keswick the ore was crushed, screened, and transferred to broad-gauge equipment for conveyance to the San Francisco Bay area. This crushing and screening equipment at Keswick was altogether too light and quite inadequate: It was constantly breaking down and maintenance costs were very high; but as long as transportation continued on the narrow-gauge railway, the upkeep of this crushing plant, plus the repairs to the locomotives and rolling stock, did not permit the abandonment of the large machine shop (a hold-over from old days of the smelter), nor any reduction in a crew of about 40 men, including the railway operators.

It was evident that, to derive the full benefit of the possible economies of the aerial tramway, various buildings, including the machine shop, warehouse, etc., would have to be located in the immediate vicinity of the upper tramway terminal and the newly constructed crushing plant, but the problem was how to find the space for them.

At this time the waters of Boulder Creek flowed through an old and none too safe wooden subway, over which it was dangerous to erect any permanent structures; but it so happened that a point of solid rock jutted out into the creek and made it take an almost right-hand turn. Advantage was taken of this to drive a tunnel, into which the entire creek flow was diverted. This tunnel was about 190 feet long and cost approximately $2,500. It was finished in November 1921. The original bed of the creek was then filled with jig tailings, providing a suitable building site with additional width for a road.

In January 1921 it appeared most improbable there would be any justification for re-opening the No. 8 mine for several years, and it was decided that, since the main operation was likely to be at the Hornet mine, the economical thing to do (from an operating point of view) was to abandon the camp at Iron Mountain and transfer headquarters to the Hornet. Some 5 months were required to make the change, which involved a great many details, including the erection of a building, combining offices, staff quarters and a store, as well as two dormitories, a school building, a boarding house and several cottages.

Up to the time of the temporary transfer of headquarters to the Hornet, the only transportation, from the level of the narrow-gauge railway at Boulder Creek to that of the Hornet tunnel, was by means of a skip operated by a hoist on an inclined tramway. This was inconvenient and unsafe for passengers, as well as expensive for supplies and freight. To obviate this bottleneck, a trail was blasted out of the left bank of Boulder Creek and subsequently was widened to permit its use as a road. This was before the days of the present efficient road-building equipment and represented a substantial expenditure.

By 1920 the deterioration of the Iron Mountain Railway had progressed to a point that required practically all new ties and rails as well as new rolling stock. The cost of operation, taxes, and upkeep had become very burdensome and, in addition, as the line was a common carrier, its operation had to conform with all the rules and regulations of the Interstate Commerce Commission as well as those of the Railway Commission of the State of California. Under the circumstances, it seemed advisable to substitute some means of transportation that was privately owned and not subjected to the restrictions, taxes, and controls imposed on the common carriers.

In spite of the very heavy capital expenditure entailed, a careful study of all the factors, such as the probable life of the mine and a continuation of the demand for pyrites, indicated that the building of an aerial tramway was economically justified. Accordingly, contracts were let and the installation of about 2½ miles of rope-way was undertaken. This provided transportation, at the rate of 75 to 100 tons per hour, for ore and pyrites from a point close to the Hornet mine to a point on the Southern Pacific Railway a few miles north of Keswick. The building of this tramway was a difficult and expensive task, partly because it involved the erection of many high towers at very inaccessible points, and the

preparation of a completely new connection with the Southern Pacific Railway, with ore bunkers, main-line railway sidings, warehouses, dwellings, etc.; but it was finally completed and started to function in the latter part of 1921. Aside from preliminary difficulties, which were quickly overcome, the aerial tramway has proved very satisfactory and economical. It has transported more than 2,000,000 tons of ore and is still delivering its daily quota. The Southern Pacific also moved its station from Keswick to the new tramway terminal, which was named Matheson. Incidentally, Keswick was named for William Keswick, who was chairman of The Mountain Copper Company, Ltd., as organized in 1896.

HORNET MINE

Particulars are not available as to just when or how the Hornet mine was discovered, but it was patented to Benjamin N. Bugbey as of August 1, 1894, and he entered into an agreement with C. W. Fielding to sell it on March 18, 1895.

On September 27, 1895, two deeds were executed by Benjamin N. Bugbey to the Mountain Mines, Ltd. (the predecessor in interest to The Mountain Copper Company, Ltd.). One of these was for the Hornet claim (19.33 acres) and the other was for 320 acres, constituting practically all the land immediately surrounding it, that is, the SE$\frac{1}{4}$ sec. 27 and the NW$\frac{1}{4}$ sec. 35, T. 33 N., R. 6 W., M. D.

The original discovery on the Hornet consisted of a very limited showing of mineralized material that projected into Boulder Creek and had been exposed by erosion by that stream. It proved to be merely the point of a triangular-shaped ore body that widened as development advanced, until at a distance of 1,200 feet from the portal of a tunnel that followed along one of the walls it showed a width of 225 feet of solid pyrite, high in sulphur but carrying only a nominal amount of copper and practically no gold or silver.

A fault was encountered that apparently cut off the ore at about 1,200 feet from the portal of the tunnel, but subsequent diamond drilling and other development indicated the possibility of some 4,000,000 tons in the original Hornet ore body, and additional ore bodies at higher elevations. However, there was no market for pyrites at that time, and it took an active imagination to see any potential value in the Hornet deposit.

In spite of this, C. W. Fielding, who was instrumental in promoting the sale of the Iron Mountain and Hornet properties to British interests, was much intrigued by the possibility of an immense mass of pyrite ore, high in sulphur, which could be used for the manufacture of sulphuric acid. He was familiar with what had been accomplished at the Rio Tinto mine in Spain, and in addition had a theory that the grain lands of California had been exhausted by constant cropping to cereals. He was sure that the application of a limited amount per acre of superphosphate (perhaps as little as half a hundredweight, as was the practice in Australia) would restore the land to its original fertility, and he foresaw the future of a wonderful development in California, based on the production of sulphuric acid to be used in turn to manufacture superphosphate.

At his instigation, a search was started at once to find a source of phosphate rock. A prospecting party was organized and proceeded to investigate every possible showing in California, but nothing was found

of commercial importance. The party then went into Nevada, but without success. Finally in Utah they met with some encouragement in the way of reports about some mysterious black rock that the local people thought was coal, but which would not burn. Following this lead, they discovered the western phosphate fields in Utah, Wyoming, Idaho, and Montana. Then followed a battle royal as to the proper method of location—lode or placer. This was finally ended during the Taft administration by the withdrawal from entry of all phosphate land; but, in the meantime, the company had acquired title to 500 acres of excellent phosphate rock and was prepared to go into the fertilizer business. A suitable plant, including a copper smelter, was erected at Martinez, in Contra Costa County, California, but it soon became evident that the farmers of California did not share Fielding's optimism regarding the benefits to be reaped from applying superphosphate to the alleged worn-out grain lands. As long as it was given to them without cost, they prepared to try it, but after a year or two, when their business was solicited on a cash basis, their ardor cooled and many of them expressed the opinion that fertilizing was a waste of money, time, and effort, because so far as grain was concerned, the real factor of importance was the weather; that is, given rains in sufficient quantities, and at the right time, the land would produce crops equal to those produced 20 or 30 years earlier. This idea was so prevalent that sales were very limited and, although the fertilizer business was continued as a sort of side-show, it fell far short of realizing Fielding's expectations.

However, the production of petroleum in California increased in importance year by year, and its refining required large quantities of sulphuric acid. In spite of the fact that the original idea had proved to be something of a disappointment, the demand for sulphuric acid in the oil industry developed a market for high-grade pyrites (about 50 percent sulphur) that equalled or exceeded the expected demand of the fertilizer business.

FIRES

Over the years there have been a number of minor fires, but because of special precautions, such as ample reserves of water and fire-fighting equipment, most of these entailed little loss or inconvenience. There were two fires, however, of major proportions; these caused temporary suspension of pyrites shipments and necessitated prompt and expensive plant reconstruction. Both of these fires occurred at the Boulder Creek crushing plant, which prepared the pyrites for shipment to the acid plants on San Francisco Bay.

The first fire was on October 25, 1924, and at the time it started the plant was in full operation. Apparently the noise of the machinery smothered the sound of the fire and it had gained considerable headway before it was discovered. Just how the fire started is not known, but it probably was caused by the carelessness of some of the mill men who had an open fire for heating coffee. There was much dry sulphide dust and this served to spread the fire so rapidly that the company's employees were compelled to drop everything and run. A train of ore cars had just entered the upper portion of the plant when the motorman noticed the fire below. He started downstairs to warn the others but was driven back by the flames and could not return to his electric locomotive, which was a complete loss. If it had not been for the efforts of the superintendent,

M. J. Murphy, it is certain that the whole upper aerial tramway terminal and surrounding buildings would have been a total loss; but by his good judgment and prompt action, the fire was confined to the rolls plant and the buildings on up the hill. Murphy personally placed and set off two charges of dynamite, each of 50 pounds, which blew out the connection between the tramway terminal and the rolls plant. To do this he was compelled to work within 8 or 10 feet of where the fire was burning fiercely, but by concentrating his fire-fighting force and all the available water on the rolls, he managed to prevent these from being seriously damaged; in fact, the babbitt in the bearings was not even melted. Most of the wooden structures, however, were destroyed.

The loss, partly covered by insurance, was in the neighborhood of \$50,000. Work on reconstruction was started immediately so that within 30 days the plant had been rebuilt sufficiently to continue regular shipments.

The second fire, which was quite spectacular and created considerable excitment, started from some unknown cause about 5:30 p.m. on November 28, 1930, after the conclusion of the day's work. Smoke was noticed by the watchman in the upper portion of the building above the loading terminal of the aerial tramway. He immediately telephoned to Murphy at Iron Mountain, who sounded a general alarm and then loaded his car with men and proceeded to Boulder Creek. He was followed immediately by the company's bus, as well as other cars carrying a total of 60 fire-fighters. In the meantime the watchman had done all he could to check the fire, but it spread very rapidly, so when help arrived both the rolls plant and the bins back of the tramway terminal were completely enveloped in flames, and clouds of suffocating sulphur smoke were rolling down into the narrow passageway between the buildings. It seemed almost impossible for men to live in that atmosphere at all. The chemical apparatus proved utterly useless, but fortunately there was plenty of water available, permitting 10 lines of high-pressure hose to be brought into play; and a stubborn and successful fight was made to save the upper tramway terminal, the machine shop, the warehouse, and the upper portion of the plant. At first this seemed hopeless, and a telephone message was sent to the district supervisor in Redding for help. He responded by ordering out the city fire department to make the trip to Boulder Creek, almost an hour's run. This done, he proceeded personally to the fire, thinking his fire department was right behind him; but the company's men appeared to be making progress and Murphy telephoned a second time suggesting the fire department had better wait 15 minutes for further advice. In less than a quarter of an hour it was apparent that the fire could be brought under control, and word was telephoned to Redding; but even so, three of the Redding firemen, in addition to the supervisor, came on to Boulder Creek.

Preventing the fire from destroying the upper aerial tramway was a wonderful piece of work, and likewise it was fortunate to have saved the machine shop, warehouse, and some other smaller buildings; but enough of the plant had been destroyed to compel the temporary suspension of pyrites shipments over the aerial tramway to Matheson. An existing contract requiring the delivery of about 40,000 tons of sulphide ore before February 28 necessitated a start on the reconstruction before the ashes were cold. The work was pushed in spite of winter rains and

shipments were resumed January 17, in time to complete the contract within the allotted period.

The loss in this fire, covered by insurance, amounted to about $32,000, but as usual this was insufficient to pay the cost of the rehabilitation.

GOSSAN OPERATION

As early as 1905 when William F. Kett was appointed assistant to Lewis T. Wright, then general manager, C. W. Fielding emphasized the importance of the large outcrop of gossan at Iron Mountain, and he urged that, whenever opportunity offered, Kett should spend a few days walking over the surface and studying the gossan occurrence. Evidently Lewis Wright had a somewhat similar idea, because he had quite a little laboratory work done to determine the possibility of utilizing this huge gossan mass, but found the costs would exceed the values recoverable.

The company's records show a preliminary sampling of the gossan over a limited area representing perhaps 150,000 tons, made by D. F. Campbell, one of the company's engineers. In 1909 a further sampling was made by T. J. Jones, who was then the mine superintendent. This sampling was also of a limited area, representing approximately 500,000 tons of gossan, which averaged $1.85 per ton in gold and silver. Under the economic conditions existing at that time, and because of the apparent metallurgical difficulties, this amount did not justify the erection of a plant to treat the material. It was not until many years later, after the perfection of the auto-truck, the marked cheapening and improvement in the cyanide process, the lowering of the costs of road building, and the introduction of cheap mining by the open-pit system, that there was any hope of extracting and treating the gossan at a profit. Under the circumstances, no action was taken. In 1913, however, just previous to his departure to join the armed forces in Italy, Gelasio Caetani, the company's consulting metallurgist, conducted some experiments which indicated that, by using a weak cyanide solution, about 85 percent of the gold could be extracted. It was not until 1928 that preliminary pilot-plant cyanide-leaching tests were undertaken by J. M. Basham, engineer, to whom much of the early success of the method adopted at Iron Mountain can be attributed. The tests undertaken in 1928 gave sufficient assurance to warrant the construction of a plant of 250 tons daily capacity, and extraction of the gossan by the open-pit method began in December 1929.[5]

Before starting the erection of a cyanide plant for the treatment of the gossan, intensive study was given to all the factors affecting the economy and the convenience of the operation, such as the best location, tailings disposal, water supply, safety of the plant and the camp from blasting, road building, transportation of ore to the mill, and disposal of overburden.

The first idea was to minimize the cost of transportation by placing the proposed plant as close as possible to the heaviest gossan showing, but it soon became obvious that such a course would create an extreme hazard from flying rocks from blasting and, because the only adequate

[5] See also Averill, C. V., The Mountain Copper Company, Ltd., cyanide treatment of gossan: California Div. Mines Rept. 27, pp. 129-138, 1931. Averill, C. V., The Mountain Copper Company, Ltd., cyanide treatment of gossan: California Div. Mines Rept. 34, pp. 312-330, 1938.

storage for tailings was about half a mile distant, there was no option about the selection of the site.

The area selected for tailings storage was a deep and narrow ravine, cutting across the course of Slick Rock Creek almost at right angles. This bore the euphonious name of ''Hogtown Gulch'' and was estimated to have a capacity of about 300,000 tons of tailings; but, by building a conveyor across it on an up-grade, the tailings were ultimately carried to such a height and were so well distributed, that the pile held over a million tons.

The first of the tailings deposited contained 50 to 55 percent iron, but toward the end of the operation the iron content had decreased to as low as 30 or 35 percent. Even so, that reserve of possible iron ore still exists and, with cheap power from Shasta and Keswick dams, may some day become a source of iron.

A water supply was already available from Spring Creek through the existing pipe line which had been built to provide water for the No. 8 flotation mill. Centrifugal pumps, operated by electric motors, were used to force this water from an elevation of 1,600 to 2,600 feet.

There were a number of cottages, cabins, and bunkhouses that the blasting would make unsafe. Most of these were demolished, including a very popular bunkhouse called ''Castle Garden.'' In spite of the danger, however, the superintendent's residence, known as ''La Casa Grande,'' and the ''Guest House'' were allowed to remain. The latter was occupied by the general manager, the consulting engineers, and various staff members on their periodical visits from the San Francisco office. Because it had been built at considerable expense and was comfortably furnished, it seemed a pity to demolish it, but the severe bombardment of rocks finally required the rear windows to be protected with heavy wire screens and a solid roof of planks topped with corrugated iron.

La Casa Grande was perhaps not as vulnerable as the guest house, but even it was the scene of a near tragedy. An especially heavy blast dropped a rock, weighing about 10 pounds, on the roof over the kitchen, and it smashed through and buried itself in the floor, just at the point where the superintendent's wife usually stood when she prepared the evening meal. Fortunately, she was absent with a committee collecting Red Cross funds and reached home only after most of the debris had been cleared away.

A considerable portion of the cost of transporting the gossan to the mill was the heavy expenditure necessary for building and maintaining adequate roads. The gossan was conveyed in large dump trucks, loaded from a power shovel at the quarry and discharged into wooden bunkers at the cyanide plant. These operated over roads cut out of the side of the mountain, but the ground was too soft to stand the heavy pounding of those trucks and the roads had to be surfaced with hard, broken stone, of which there was very little available locally. The result was the roads became a sea of mud in the winter and were covered deeply with dust in the dry season, causing undue wear on the vehicles and correspondingly heavy repair bills.

In the beginning, there was practically no overburden to be removed by the power shovels. Later, however, it became a real item, for sometimes as much as 10 tons of overburden had to be removed to obtain one ton of gossan; and the volume of overburden dumped into the bed of

Slick Rock Creek eventually became so great that it made an enormous fill right across the gulch.

The excavation of the gossan started at the toe of the deposit, and when the lower portions of the overburden and gossan had been removed nothing was left to hold the immense upper mass, and it started slipping. This was very gradual at first, in fact almost imperceptible, but it was also irresistible, and great care had to be exercised to prevent accidents to equipment and men from rock slides that occurred occasionally.

In one instance a remnant of a rather good grade of gossan was being extracted with a power shovel when the frequency of slides increased to such an extent as to make it advisable to substitute an underground method of "top slicing." This required a large expenditure for preparatory underground work and, while it was successful in extracting the ore, the outcome was a controversy with the United States Treasury Department, and the payment of excessive income taxes.

In another case, a considerable quantity of gossan had been taken from a pit below the level of one of the operating floors, and the pit permitted to fill with a mixture of overburden and water. It looked firm enough on top, but suddenly on a Sunday morning, when fortunately only a few men were working on the outer edge of the quarry, there was an especially large slide which apparently landed right on top of the fill in the pit. This squeezed out the mud and boulders and thousands of tons kept going right on down to Slick Rock Creek, wiping out the company's office, the mine store, and other buildings.

Superintendent J. G. Huseby was eating breakfast in his home immediately below the quarry when the slide occurred. Alarmed by the noise, he rushed to his front porch overlooking Slick Rock Creek and observed the approach of the wall of mud and boulders. Occupants of the boarding house, aroused by his shouts, dashed from the building constructed over the creek-bed, just before the mass struck. This was most fortunate as a good portion of the underpinning was swept away, dropping the entire lower floor and contents into the swirling mass.

The progress of the flood was slow (only slightly faster than a man could walk) but relentless. The next things it encountered were the office and garage directly below the superintendent's residence. One occupant of the office had similarly been alarmed and scurried to safety. The building shuddered a moment, swung partially around, then collapsed completely and swept onward. The garage with the superintendent's car in it was lifted bodily to the crest of the flood, then rolled to one side some 50 feet farther on, against the electric shop.

Fifty yards farther downstream the warehouse with approximately $15,000 in contents was demolished and carried away. The general store suffered a like fate to the boarding house; its underpinning removed, the floor and merchandise collapsed into the turbulence below.

The flood dissipated itself another 200 yards farther on, leaving along its route through the entire camp huge boulders, mud, and debris 6 to 8 feet deep, and the private automobiles which had been parked in its route. In all, 13 cars were wrecked, six completely, the others almost equally so. Fortunately for the citizenry, however, an enterprising insurance agent had only a short time before covered all except one car, so the major loss was entailed only by the company.

A short distance below the store, and just before the flood stopped, a small shovel was being operated in the creek bed on road improvement. Its operator, being distracted by the noise of his machine, was unaware of his peril until the wall of buildings, automobiles, mud, and boulders was almost upon him, but he leaped from his cab and reached the bank in safety.

Power shovels and caterpillars from the quarry were used to reopen the road so operation could be resumed that evening, but weeks of arduous and dirty work were required before the entire mess was cleared away. Temporary boarding facilities and offices were established in adjoining residences, where they exist to this date. One lesson was learned—never to build on a canyon floor.

As previously stated, the potential value of the gossan was recognized by Fielding at an early date, and the search for an economical method of treatment was followed persistently until eventually it was brought to a successful conclusion in 1928 by a series of pilot-plant leaching tests conducted by J. M. Basham. These gave the assurance needed to warrant the construction of a plant for treating 250 tons per day, which resulted in the start of gossan-mining operations in December 1929.

Early practice encompassed dry crushing with jaw breaker and rolls to three-quarters of an inch, followed by straight sand leaching in weak cyanide solutions. Leaching was performed in redwood tanks 26 feet in diameter and 10 feet deep, with canvas filter bottoms. A 5-day leaching cycle was first employed, with progressively more barren solutions, and a final water wash and drain. Precipitation was performed by the Merrill-Crow process, and bullion melted on the property.

Continual experimental work showed the advantage of finer crushing, and a $\frac{3}{8}$-inch screen product was resorted to. Plant additions proved warranted and tonnage was increased in 1930 to 500 per day. A further extension made in 1932 brought the capacity up to 600 tons per day.

As quarry operations progressed under increasing overburden, metallurgical difficulties arose due to the fact that natural slimes impeded sand leaching. In 1938 it became necessary to supplement sand leaching with a counter-current decantation slime-treatment plant. A 40- by 36-foot three-compartment Dorr balanced-tray thickener was installed, followed by a 50- by 60-foot five-tray washing thickener and two 29- by 12-foot agitators. Dry crushing was followed by grinding in solution in a 24- by 24-inch Jeffrey swing-hammer pulverizer, and classification in a Dorr DSF 11-foot bowl classifier.

All changes were the result of aggressive and continual laboratory experimental work by successive mill superintendents, E. M. Bagley, J. M. Basham, J. G. Huseby, and D. L. King. Innovations employed were varied and numerous, and included upward leaching, block leaching, pressure leaching, pneumatic agitation, and induced channeling.

Experiment was equally prevalent in mining practice. Operations were begun in 1929 with a quarter-yard Insley excavator and two 4-cubic-yard solid-tired AC Mack dump-trucks. The haul was approximately half a mile round trip on a level dirt road. Winter conditions were most severe.

In the fall of 1930 a $\frac{3}{4}$-yard Bucyrus-Erie 1030-B electric shovel, and additional Mack 4-yard dump-trucks, were purchased to facilitate

handling of burden. Successive years saw the purchase of additional shovels: Lima 101 1½-yard, Bucyrus-Erie 37-B 1½-yard, Model 6 Northwest 1½-yard, and Bucyrus-Erie 54-B 2½-yard. Truck sizes were increased to 10-yard semi-trailers, and pioneer work was done on the use of large pneumatic tires.

To the company's credit must also go the pioneer work in the adaptation of contractors' excavating equipment to mining practices. Bulldozers were early resorted to, 18-yard Le Tourneau bottom-dump buggies received trial, and 16-yard Athey side-dump trailers. Another interesting innovation was the eventual employment of Le Tourneau carry-all scrapers and rooters in the mining of surface ore. This activity was established on the very crest of the mountain and the ore brought to the quarry berm, over which it was bulldozed to the quarry floor, 400 feet below, where it was reloaded by shovel and transported to the mill.

In a third method of mining employed on gossan, underground top-slicing was resorted to. This activity was confined to a higher-grade zone where open-pit mining was precluded by extreme burden ratio and moving ground. Operations were commenced in January 1939, and carried to completion under the direction of C. W. McClung, mine superintendent.

All gossan mining ceased in February 1942 because of economic conditions and the threat of labor shortage incident to preparation for war.

Under the direction of M. J. Murphy, superintendent, and J. G. Huseby, mining engineer, an extensive churn-drilling campaign was undertaken in 1931 to define the outline and prove the value of the oxidized or gossan capping. Briefly, the gossan body was projected from its southwest cropping for a distance of 1,800 feet on a northeasterly strike at an incline of approximately 15 degrees. The body was tabular, and largely rectangular, maintaining an approximate width of 500 feet, and attaining its maximum thickness of 250 feet over the Old mine sulphide body. Maximum gold values were likewise encountered in this area. As the ore body progressed northeastward, it decreased to a maximum thickness of 75 feet. Gold values diminished and overburden ratio increased to as much as 10:1. Overburden was largely composed of oxidized and decomposed porphyry, though some lenses of unaltered alaskite were encountered.

It is interesting to note that the depth of oxidation approximated 500 feet in places. Equally worthy of comment was the occurrence of highly iridescent and brilliantly colored vug linings in portions of the ore body. One mammoth cave was encountered on the footwall of the Bears Den claim with typical stalactite and stalagmite formations, indicating the migration and precipitation of iron-bearing solutions. Such migration resulted in the deposition of limonitic clay in all vugs, contributing largely to the metallurgical difficulties, which eventually arose when natural slimes were encountered in proportions as high as 30 percent. However, the extreme porosity of the ore body was the major factor contributing to its successful treatment. This permitted migration of the soluble copper and ferrous sulphates so that no metallurgical difficulties were encountered, except in the lowest extremity of the ore body.

One significant feature of Iron Mountain geology is progression of the chalcopyrite vein system right up to the secondary sulphide zone,

and even to the gossan zone, indicating the possibility of a roof-pendant character of the latter. No geologist has commented on this, however, and no late study has been made of the Iron Mountain sector. Recent geological study has been confined to the Hornet ore body, and has resulted in the extension of the known pyrite body and discovery of border phases enriched with copper and zinc minerals. Credit for this is largely due to the intensive study made by L. C. Raymond, mining engineer and geologist, who joined the staff early in 1931. He was particularly interested in the geology of the original sulphide ore bodies and gave a great deal of his time to the study of the local ore occurrences. It was through the making of thin sections of the various phases of altered rock that one particular porphyry was found to be nearly saturated with microscopic grains of primary magnetite and hematite. This was the first direct evidence of the association of the early magnetite mineralization with the so-called alaskite. Oxidation of this material forming the border of a particular porphyry resulted in a characteristic pink-colored rotten stone which made it possible to outline the porphyry plug roughly on the surface. The actual contact was found to contain in places some sulphide replacement. This is the basis of the ''hot plug theory'' (local term) which is in essence that the original massive sulphide ore bodies were structurally related to favorable bends along the contact of this particular type of porphyry or were replacements in faults extending from the contact of the porphyry itself.

To test this theory, Raymond suggested putting down a series of diamond-drill holes from the surface so as to penetrate the border of the plug at what was projected to be a distinct structural bend. The first hole struck massive sulphide ore in the structural bend at a depth of 361 feet. The core assayed 47 percent sulphur, 2.64 percent copper, and 2.26 percent zinc. It continued for 42 feet. Other diamond-drill holes in the neighborhood, penetrating the same structure, confirmed the findings in the first hole. Extraction of this copper-zinc ore was started early in 1945 and subsequent diamond drilling has continued to add to its reserves.

Development of geological knowledge concerning the various ore occurrences at Iron Mountain and the Hornet mine was necessarily slow, largely because of the extensive and complex zones of sheared and brecciated alaskite porphyries and, further, because of the different habits of the ore bodies themselves. Such circumstances did not lend themselves to brief examination work, and for this reason most of the geologists and mining engineers were able to examine only portions of the property at the various stages of its development.

The early work of Diller (done prior to 1906) indicated many of the broader and general geological aspects of the region. It was supplemented in 1906 and 1907 when Graton and Butler visited Iron Mountain and adjoining areas of the copper belt in Shasta County for the United States Geological Survey. Unfortunately, complete details of their work were never made available to the public, although a preliminary report contributed much to the knowledge of the Old mine supergene copper ore body, as well as to the nature and origin of the principal igneous rocks, namely, the alaskite and meta-andesite. Shortly after this field work was completed, the low-level tunnel of the No. 8

mine exposed the first portion of the chalcopyrite vein system and initiated a new era in the company's mining operations at Iron Mountain, that is, under the Old mine, or original ore body. Later, as an aid to mine development, a more detailed mapping of this chalcopyrite vein system was required and, to meet this need, Oscar Hershey undertook the careful logging of the extensive diamond-drill cores. These had accumulated over many years, but he was the first to make the attempt to map and classify the complex zones of altered rock on a mine-map scale. This work showed that the alaskite was not a single unit of igneous rock, but rather various phases of altered porphyries.

WAR-TIME PRODUCTION OF COPPER AND ZINC

Gossan operations of The Mountain Copper Company, Ltd., were closed down February 1, 1942, for economic reasons. This left the company with only its pyrites operation in Shasta County, in a war-time high-cost-production era. However, the critical scarcity of base metals, and the incentive premiums offered for them, directed the management's attention to the potential values of its Mattie ore body, previously discovered in driving the Richmond adit.

A prior diamond-drill exploration of this body in 1939 had revealed the existence of some 180,000 tons of possible ore containing 2.25 percent copper and 3.50 to 4 percent zinc. Preliminary metallurigical tests on samples of this ore by E. F. Robinson, company metallurgist, at its Martinez laboratory, encouraged him to outline the economics of a flotation mill for the management's consideration. Possible recoveries were indicated at 75 percent of the copper and 40 to 45 percent of the zinc. On the tonnage of the Mattie ore body alone, the venture was not very promising, but coupled with the Richmond Extension ore body, of a similar nature, the exploration of which was currently in progress, a decision to contribute to the war effort was made.

Room for a treatment plant of the extensive dimensions indicated was not available at the site of the then-existing crushing plant and the upper terminal of the aerial tramway, hence many and various locations had to be considered. It was finally decided to construct the new plant at the Richmond mine adit-level and to incorporate in the program the eventual transfer of all crushing and milling activities to this site. Authorization was received from the board of directors in London in early September 1942, and an access road to the site was commenced on the fourteenth day of that month.

Excavation went forward rapidly, thanks to the vast amount of suitable equipment retained by the company from its quarry operations. Ground work and foundations were completed by December 10. In the meantime, dismantling crews were employed at the abandoned Big Canyon gold mine and Iron Mountain cyanide plant, whence much of the material needed for plant equipment and buildings was acquired.

J. M. Basham, superintendent at the company's Big Canyon property, was prevailed upon to undertake the design and preparation of the plans for the plant, a task which he performed in a most able manner, keeping fully abreast of the demands of the local engineering staff for construction details. Bert Stewart, former carpenter foreman, was brought back from retirement October 1 to supervise construction until May 1, 1943. Reason Elder carried construction to completion thereafter.

Mine bins, warehouse, and crushing-plant facilities were completed by December 25 and erection of the grinding and flotation plant commenced January 5. Crushing of pyrite ore began in the new crushing plant on May 24, 1943, although the plant was not completed until July 5, when actual operation commenced.

In the meantime, E. M. Bagley, formerly employed by the company as mill superintendent in 1929-30, was re-engaged on January 1, 1943. He devoted his attention to a final study of metallurgical procedure, completing details coincident with the starting of the plant. Briefly, the flow-sheet adopted consisted of reducing the mine run to $\frac{3}{8}$-inch size through the medium of a closed circuit of gyratory crushers and rolls, after which this $\frac{3}{8}$-inch product was ground in two primary 7- by 6-foot ball mills in closed circuits with two DSD Door classifiers. Overflow from the two primary classifiers was reground to minus-250 mesh in a 6- by 10-foot Allis Chalmers mill in closed circuit with a DSF Dorr bowl classifier.

The copper circuit consisted of five 56-inch Fagergren rougher-flotation cells followed by one similar cleaner cell, all with $7\frac{1}{2}$-horsepower motors. These were operated without prior conditioning. Thickening was performed in a 24- by 10-foot Dorr thickener prior to filtration on two leaves of a four-leaf Eimco filter. Copper tails were pumped to conditioning storage and activated with copper sulphate for flotation in the zinc circuit. Retention in the conditioner totaled 30 minutes. Roughing was attempted in a bank of five 56-inch Fagergren cells followed by two similar units for cleaning. Zinc cleaner tails were pumped to a 7- by 5-foot Marcy mill for regrinding in closed circuit with a Dorr turret-bowl classifier from which they were returned to the conditioner. Thickening and filtering were performed in the same manner as in the copper circuit.

Anticipated results in the copper circuit were obtained from the start, though changes were made progressively to improve the metallurgy. These consisted principally of the addition of three cells in series to the rougher circuit, when the separate cleaners were discontinued. Eventually a regrind of the middlings was attempted, with a slight further improvement of the metallurgy.

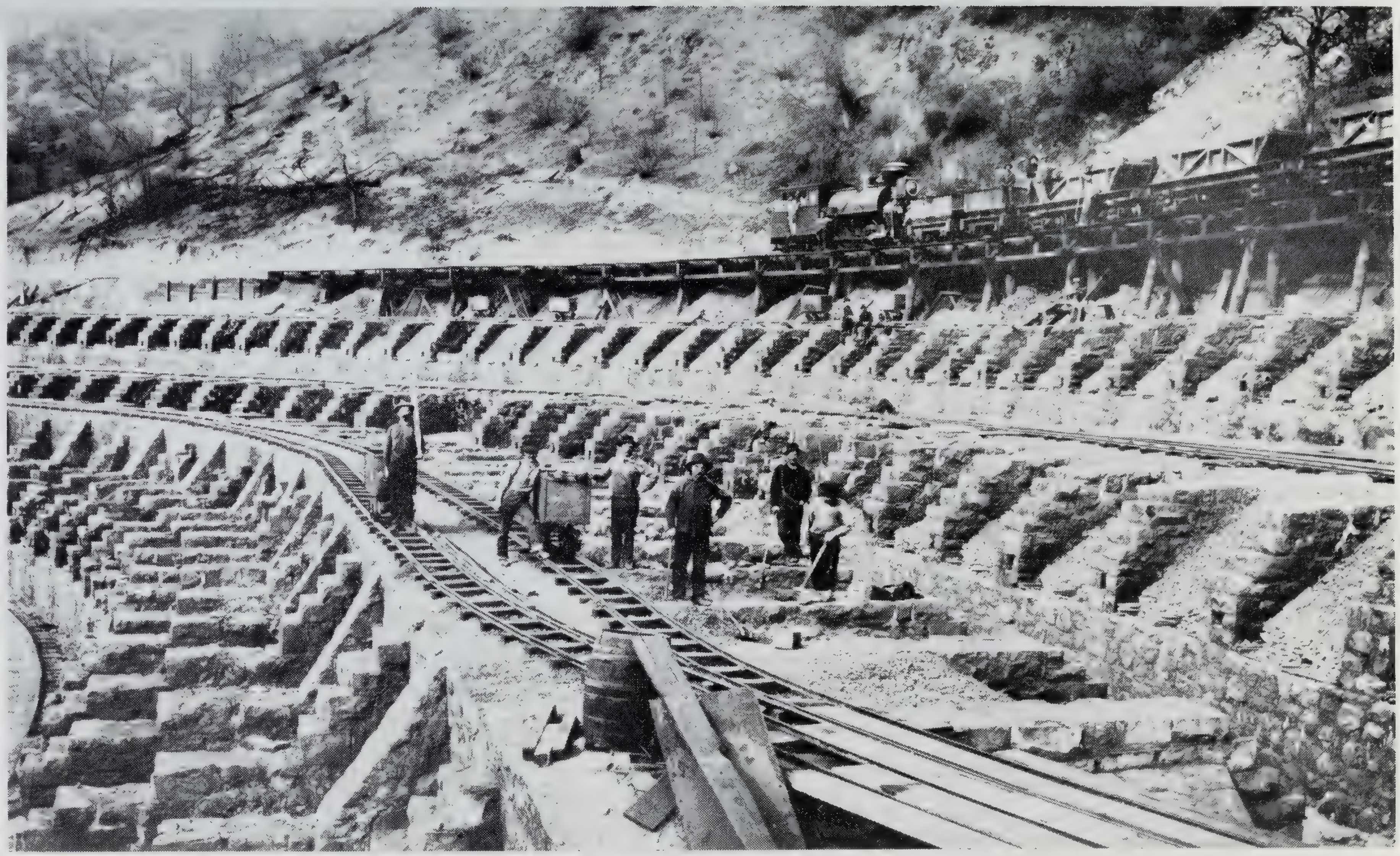
Results in the zinc circuit were not so gratifying. During the early months of operation it was most difficult to obtain a shipping grade of concentrate, 47 percent being the minimum acceptable to the smelter. This difficulty, although never entirely overcome, was eventually minimized to a degree that rendered the daily averages consistently satisfacfactory. To effect this, it proved necessary to heat the zinc circuit with live steam. Experiments along these lines were conducted during the spring of 1945, and a modern 75-horsepower boiler was installed by fall of the same year. Steam is admitted to the conditioner tanks through Schutte-Koerting cast-iron heaters and temperatures are maintained in the circuit at 80 degrees Fahrenheit.

Previous to this, considerable experimental work indicated the need for corrections to the grinding circuit to prevent undue sliming. Two mills had been employed, charged with 3- and 4-inch balls for 250 to 300 tons per day. It was subsequently determined that only one primary mill was required, for tonnages up to 375 per day, and that the use of 2-inch

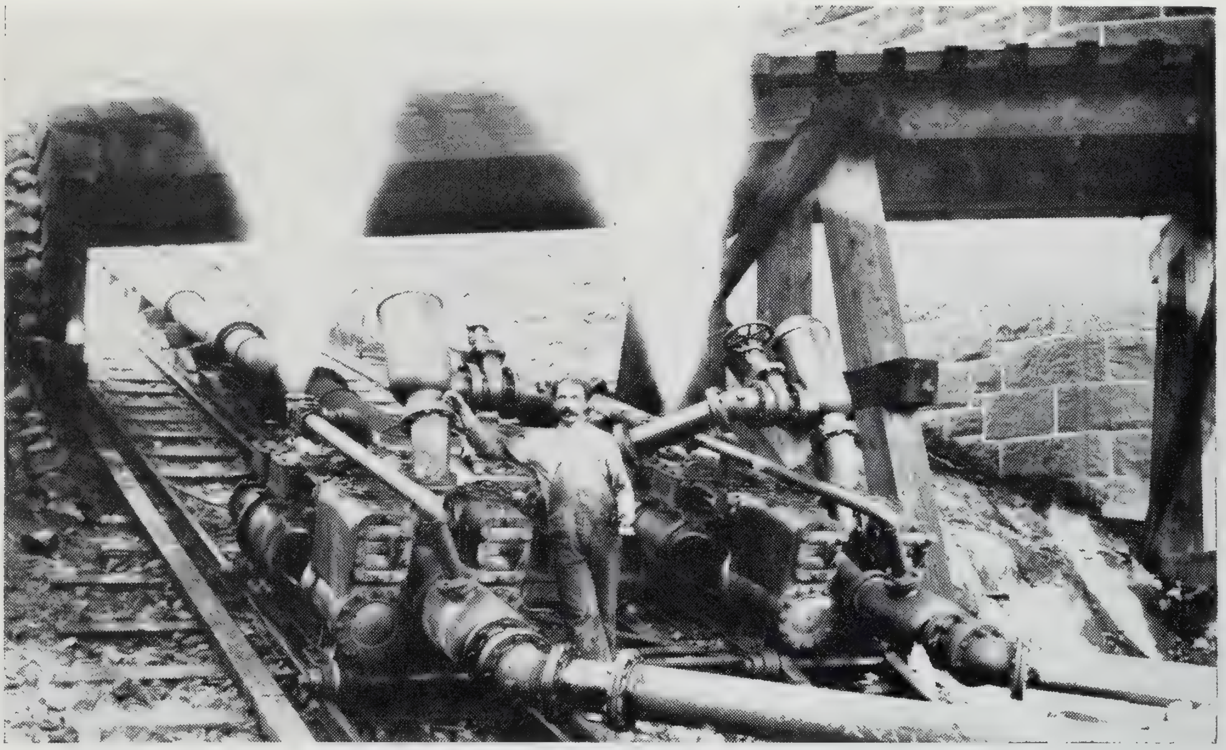
RAILWAY YARDS AT KESWICK, 1898

(KESWICK SMELTER IN 1897)

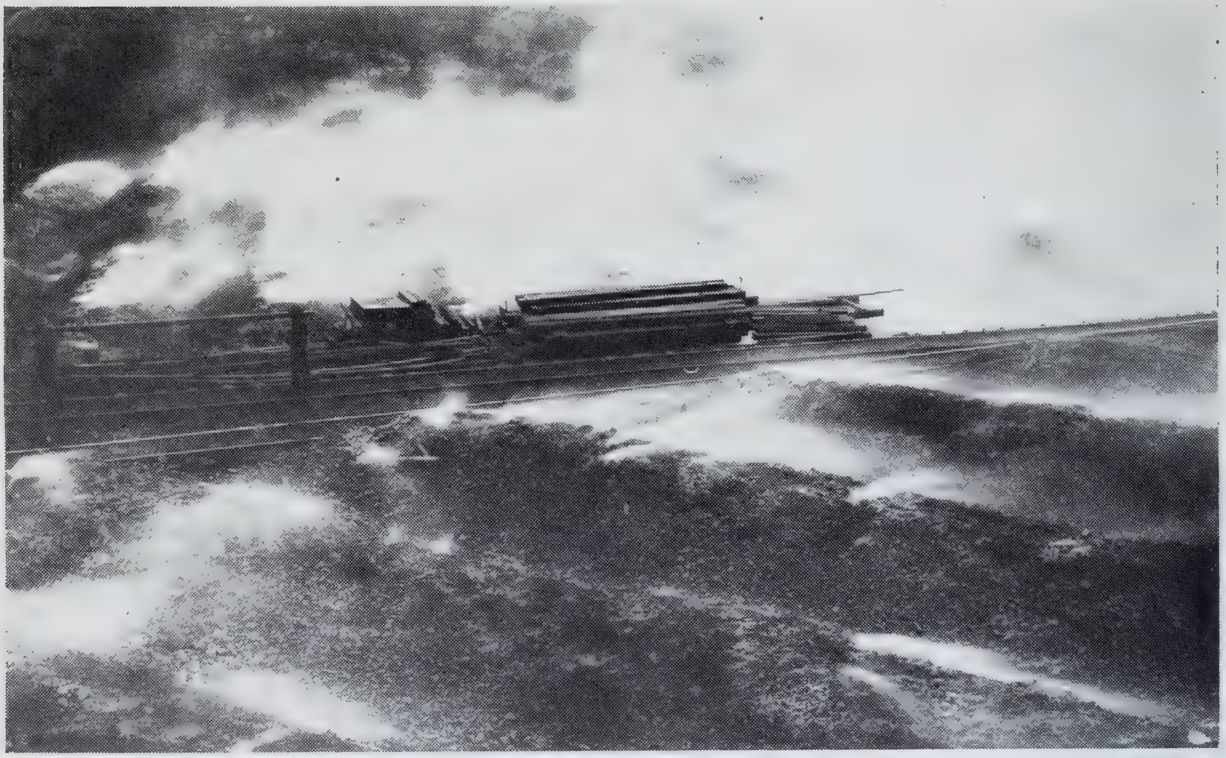
Only three blast furnaces had been built; equipment did not yet include common stack, dust chambers, converter plant, hot-blast stoves, mechanical roasters, or foundry.



ORE IN STALLS READY FOR ROASTING, 1895-96



A, SACRAMENTO RIVER PUMPING PLANT NEAR KESWICK IN OPERATION
Railway trestle over pump carries the spur leading to the wood-delivery platform on the river, 1901-02.



B, HEAP-ROASTING PYRITIC ORE AT THE KESWICK SMELTER, 1897-98

balls effected a more uniform grind. Optimum grind proved to be 85 percent minus-325 mesh.

Other experiments led to the installation of two additional cleaning stages, and subsequently of 5 additional rougher cells. Endless experiments were conducted on reagents in varying amounts and kinds, and at the time of writing these are still in progress. Some encouraging results have been obtained with recent extractions in the copper circuit exceeding 80 percent and zinc extractions running up to 55 and 60 percent, with a consistent shipping grade possible. Tonnage likewise has been increased to as high as 460 per day.

Many variations in the character of the ore contribute to the metallurgical difficulties. In the first place, fluctuations of head values in the mill vary from 1.5 percent copper and 2 percent zinc to 3.5 percent copper and 8 percent zinc, with even greater fluctuations underground. Considerable oxidation has occurred to copper on cleavage planes, and a high percentage of marmotite, with varying iron content, contributes to the difficulty in the zinc circuit. The greater portion of mineralization is finely disseminated through, and interlocked with, the pyrite matrix; though in places a later phase of chalcopyrite enrichment is noted in cleavages. Also, soluble sulphates are present in detrimental quantities.

It was early determined that the age of the ore, after mining, had a direct bearing on metallurgical results. This was even more true of the Mattie ore body than of the Richmond Extension. Extraction would drop off radically on an ore blasted for more than one week and crushing aggravated this situation.

Mining

Many of the above factors were known, or surmised, before the mining system was established. Prior to its inception, C. W. McClung, who had been in charge of sub-level caving in the "West End" gossan underground mine, was made mine superintendent and placed in charge of development of the Mattie ore body. This ore body lent itself ideally to diamond-drill blast-hole mining, and such a system was established,[6] with a scram drift driven each way from a central incline shaft at the bottom of the ore body. Undercutting was completed through its entire length and a narrow vertical stope opened at each end toward which blast holes could be broken. Diamond-drill blast holes were drilled vertically in ring pattern from a central adit near the back. A maximum of 7 feet of ground was broken with each ring, and holes spaced no more than 10 feet apart at their extremities. Longest holes were perhaps 75 or 80 feet in length. Sixty-percent gelatine powder was used for blasting.

Fair results were obtained at first, but as the stopes grew larger on each end, considerable overbreak and caving resulted in large boulders and necessitated secondary blasting. Some wall dilution occurred all through the mining of this body, but practically 90 percent of the anticipated ore was extracted before the final cave-in resulted. Retarding of this was assisted by the large transverse pillar (about 30,000 tons) required to sustain the main haulage to the pyrite ore body. Final computations indicated 121,880 of the original 180,000 tons recovered.

In the meantime, raises and entries to the Richmond Extension ore in the main pyrite ore body had been completed and the transfer made

[6] See also Huttl, J. B., Diamond drilling features Mountain Copper's mining: Eng. and Min. Jour., vol. 147, no. 9, pp. 64-68, Sept. 1946.

with only a slight temporary cut-back in tonnage. Because of the more tabular form of the Richmond ore body, diamond-drill blast holes were drilled flat from stope ends over the undercuts. Later, they were entirely abandoned in favor of machine blasting.

With the return to conventional rock-drill mining, stopes were established at right angles to the main slushing drifts. Pilot raises were driven under an acceptable safe curtain and stope widths established at about 30 feet by slabbing to the pilot raises. When arching of the backs had been accomplished through the entire length (150 to 200 feet), subsequent mining was by underhand stoping. Twenty to twenty-five pillars were left between stopes, and as completion permitted, these have been reduced in size by interlocking raises and diamond-drill slabbing. The estimated recovery as stoping progresses is 70 percent. This can probably be increased when the extremities are reached and a general retreat is permissible.

In the meantime, diamond-drill exploration has been in progress both underground and on the surface. This has so extended the known boundaries that there remains more ore for extraction than the quantity upon which the operation was projected.

Surface Facilities

With the completion of the mill on July 6, 1943, attention was immediately directed toward the complete transfer of all surface facilities to the new plant site. This was temporarily delayed by an explosion of the company powder magazine on the Richmond level July 20, 1943, when approximately 11 tons of 40-percent and 60-percent dynamite exploded. The explosion was preceded by a fire at the magazine, fortunately discovered by the train crew who spread an immediate alarm. The 2 or 3 minutes of warning given permitted evacuation of nearby buildings, so only two incidents of slight injury to employees resulted.

The blast shook the entire vicinity and was heard and felt as far as Redding, 17 miles away. Concussion and shock tore corrugated iron from all new mill structures, and in some instances twisted girders and structural steel beyond repair. Despite this, however, after a preliminary clean-up, the mill was able to resume operations in less than 24 hours, although forest fires were fought for days thereafter. These had broken out immediately in all directions, within a radius of three-quarters of a mile. No cause for the explosion was determined, though it was suspected that an open-flame lamp had been carried into the building by the nipper 15 or 20 minutes earlier.

A new site was selected for the powder magazine and one of the earliest structures completed was a modern sand-filled approved-type magazine at a safe distance from all operations. Simultaneously, a fully modern change room and mine office building were erected on the new level. The result not only became a source of pride, but also effected a total saving of nearly half an hour per shift in transportation of miners.

With the completion of the change room and powder magazine, there followed in succession the construction of a mine-car repair shop, a steel-sharpening shop, welding sheds, machine shop, and garage. Modern equipment was installed in all of these. Transfer to these shops was completed by October 1944 and attention was then directed toward the erection of a new compressor building, housing an Imperial-type 10 Ingersoll-Rand compressor and a modern PRE compressor, together with a motor

generator set to provide direct current used in the operation of the underground trolley locomotives. During the spring of 1945 a new and modern warehouse was added, which, with a framing shed, pipe shop, steel racks and greasing station, completed the immediate building program.

There remains (May 1946) to be provided buildings for general mine offices and tramway terminal; this will consolidate all operating facilities on the one level. The results of these changes and improvements have been most gratifying from the standpoint of efficiency and economy.

It might also be mentioned that a marked effort has been made by the company to improve living accommodations in its community. During the past 10 years all houses have been modernized, bathrooms have been added, and interiors redecorated.

A further point of interest has been the company's continual improvement of road conditions—by replacing old railroad trestles with culverts and fills, widening and surfacing, and finally, with federal aid, by constructing an oil-surfaced road which, in connection with the county roads and state highway, provides a first-class means of motor transportation between Redding and the company's operations.

Incidentally, one of the factors that contributed to the solving of the metallurgical problems was a quick method for the determination of the grade of the zinc concentrates. This was worked out by Henry Clineschmidt, one of the company's assayers, and was based on the direct relation of the iron to the zinc; that is, a simple determination of the iron served as an indication of the percentage of zinc present in the concentrates, from hour to hour, as currently produced.

SHASTA COUNTY PERSONNEL OF THE MOUNTAIN COPPER COMPANY, LTD., FROM 1895 TO 1946

General Managers

Gilbert McM Ross, 1895; Alexander Hill, 1896-97; Lewis T. Wright, 1897-1911; William F. Kett, 1911-46; Laurance T. Kett, 1946-.

Gilbert McM Ross. Early in 1895 Gilbert McM Ross was appointed as manager or superintendent, with headquarters at Iron Mountain. At that time the mine development was in progress for Mountain Mines, Ltd., and the property was not taken over by The Mountain Copper Company, Ltd., until December 1896.

Ross came to the United States from Scotland about 1875, and his first position was as assayer in Virginia City, Nevada. At the age of twenty he was assistant assayer at the United States Mint in Carson City, Nevada. Later he owned a mine and mill at Dun Glen, Nevada, and was superintendent of several of the big bonanza mines. Just previous to undertaking the development at Iron Mountain, he had been manager of the Union copper mine at Copperopolis, Calaveras County, California. Associated with Ross at Iron Mountain were H. Pinckney Winslow and Leonard Coleman; W. H. Freeland and Henry Schlund were the assayers.

Alexander Hill. Gilbert Ross resigned about the end of 1895, and was followed by Alexander Hill, the first "resident manager" sent out by the Board of Directors in London. In 1897, however, Hill returned to England.

Lewis T. Wright. The Board next appointed Lewis T. Wright as manager, who took over the work in 1897 when Alexander Hill returned

to England. Wright's task was a very strenuous one, involving many business difficulties as well as technical and metallurgical problems. However, for the next 10 years, or until the rich ore of the Iron Mountain deposit was practically exhausted, the company earned substantial profits under his management.

William F. Kett. In 1905 William F. Kett was appointed assistant manager to Lewis T. Wright. At the time of his appointment he was resident in England, and was told by the managing director that, because of the probable early exhaustion of the rich Iron Mountain ore body, the Shasta County operation might terminate within 4 years; that is, that the job might be of temporary nature. Notwithstanding this intimation, Kett decided to "take a chance". After more than 41 years of service, he expressed himself as feeling quite sure the enterprise was a "good bet" for at least another half century.

Following Lewis T. Wright's resignation in 1911, William F. Kett became general manager. He retained this position until October 1946, when he resigned.

Laurance T. Kett was appointed assistant manager by the Board on January 1, 1935. He had familiarized himself thoroughly with the details of the company's business through years of apprenticeship, serving in various departments and capacities. At the end of September 1946 he became general manager, succeeding his father, William F. Kett. He holds the position of general manager at the present time (1946).

Assistant Managers

H. Pinckney Winslow, 1895-96; W. H. Freeland, 1898; Lancaster, 1899; Henry E. Edwards, 1899-1901; Arthur Harley, 1904-05; William F. Kett, 1905-11; Laurance T. Kett, 1935-46; J. G. Huseby, 1946-.

H. Pinckney Winslow arrived in California from London in mid-1895 and remained as assistant manager at Iron Mountain until the latter part of 1896, when he returned to England.

W. H. Freeland. When Alexander Hill took over the management in 1895, he appointed W. H. Freeland as mine superintendent at Iron Mountain; at the same time Winslow was made assistant manager with headquarters at Keswick, to which point Leonard Coleman was also transferred. As soon as the first blast furnace was ready to operate at Keswick in 1896, Freeland left Iron Mountain and assumed the duties of smelter superintendent, in which capacity he continued until 1898, when Wright appointed him assistant manager to succeed Winslow, who had returned to England. However, in the latter part of 1898, Freeland left to take the management of the Ducktown Copper Company at Ducktown, Tennessee, which post he retained for 12 years. After retiring, and until the time of his death about 1931, he made his home at San Rafael, California.

Mr. Lancaster followed W. H. Freeland as assistant manager, arriving in January 1899. He returned after a few months.

Henry E. Edwards succeeded Lancaster as assistant manager, having been appointed by the Board of Directors in London. He is reported to have been a very able metallurgist and a capable smelter man, but not very adept as an executive. He left in the early part of 1901.

Arthur Harley was the next assistant-manager appointee from London. He arrived in 1904 but was recalled in 1905.

J. G. Huseby. In 1930 and 1931 the company's staff in Shasta County was supplemented by two graduate engineers from the Oregon School of Mines. These were J. G. Huseby and L. C. Raymond. The former was appointed M. J. Murphy's assistant, while the latter took over much of the underground surveying and mapping, which enabled him to make a special study of the local geology.

Huseby's duties brought into close contact and familiarized him with the daily problems confronting the superintendent and, when Murphy died suddenly, he was thoroughly qualified to carry on, which he did until August 1946, when he was appointed assistant manager and was succeeded as general superintendent by C. W. McClung.

General Superintendents of Shasta County Operations

T. J. Jones, 1903-09; Willard L. Cole, 1909-18; M. J. Murphy, 1918-35; J. G. Huseby, 1935-46; C. W. McClung, 1946-.

Willard L. Cole was first employed by the company on September 15, 1895. He had previously been connected with the engineering department of the Southern Pacific Railway and he began work with the company as a surveyor on the line of the Iron Mountain Railway. Subsequently he did some preliminary surveying on the Sacramento, McCloud, and Pitt Rivers with a view to developing water power for the Keswick plant. When this survey was finished, he acted for a short time as assistant mine superintendent at Iron Mountain under F. E. Willson, but resigned and went back to his home in Oregon. However, Alexander Hill telegraphed and offered him the position of superintendent of the Iron Mountain Railway, including the machine shops and construction work. Cole accepted and until 1905 was in full charge of the building and maintenance of the Keswick plant, the Iron Mountain Railway and their various auxiliaries. At this time (in 1905) the company's new plant at Martinez had been completed and Cole became its first superintendent. In 1909 he was again transferred to Iron Mountain as general superintendent of the company's operations in Shasta County. He resigned in 1918 and was succeeded by M. J. Murphy.

M. J. Murphy worked for the company at intervals over a period of almost 39 years. He started at Iron Mountain in December 1896, operating a machine drill, but quit in June 1899 and did not return until early in 1903, when he worked as shift boss under J. J. Shaw. He held this job until September 1905, when he left again. He did not come back until March 1908, when he applied for work and was given a job as shift boss at the Hornet mine under McLennen, who was the foreman at that time. He worked at the Hornet mine for a few weeks, then was transferred by T. J. Jones, the general superintendent, to Iron Mountain, as foreman in charge of sinking a three-compartment shaft and developing the No. 8 mine.

When W. L. Cole retired in 1918, Murphy's most excellent work during the previous 10 years, as foreman in developing and operating the No. 8 mine, left no doubt but that he had the requisite qualifications for the post of general superintendent, and he was duly appointed. The next 17 years fully justified this selection, and his sudden death in August 1935 was a severe misfortune to the company, as well as a source of

much sorrow to his host of friends and associates. Murphy was a mining executive of outstanding ability, a man of the highest integrity, with sound business judgment, animated by a spirit of faithfulness and loyalty. He possessed the faculty sometimes called "a nose for ore," which, coupled with his continued and conscientious efforts to advance the interests of his employers, rendered his services of inestimable value and contributed materially to the success of the company's Shasta County operations.

C. W. McClung, the present general superintendent in Shasta County, is another member of the staff who has worked intermittently for the company over a number of years. He started at Iron Mountain in March 1931, left in November of that year, and returned in October 1932; he left again in March 1933. In 1934 McClung joined the company's staff at the Big Canyon mine in El Dorado County, where he remained until transferred to Iron Mountain in March 1940. His supervision of the mining at the Big Canyon, Iron Mountain, and Hornet has been characterized by sound practical judgment coupled with the ability to secure maximum economy.

Attorneys

The first attorney for the company in Shasta County was Clay W. Taylor, appointed by C. W. Fielding in 1894 or 1895. Taylor became seriously ill in March 1896, and never recovered. Some time before his death, he recommended W. D. Tillotson, an attorney who had established himself in Redding in January 1896. Tillotson succeeded Taylor as the company's local legal representative, and has continued as such to the present time (1946).

Charles P. Eells of San Francisco was appointed early in 1897, and for almost 16 years continued to handle much of the company's legal business, except such as pertained to local matters in Shasta County. However, in September 1912, C. W. Durbrow succeeded Eells, and is still the company's legal adviser in San Francisco (1946).

Consulting Engineers

During the first few years, when the development at Iron Mountain was in progress, H. H. Knox, of the firm Knox & Allen, did much of the consulting work; but in 1913 the firm of Burch, Caetani, & Hershey was definitely appointed to make periodical inspections and submit reports to the London directors.

Albert Burch was the senior member of this firm, and specialized in underground developments and mining methods. Gelasio Caetani was a metallurgist and Oscar Hershey a geologist. This combination made a strong team that rendered most valuable advice.

However, when World War I started in 1914, Caetani felt in duty bound to return to Italy, his native land, where he joined the armed forces. This left a vacancy in the firm which was filled from 1919-29 by Lloyd C. White.

Prior to 1914, White had been in charge of some development work in British Columbia for the Portland Canal Mining Company, but in July 1914, on the recommendation of Burch, Caetani, & Hershey, he was employed to supervise the erection and operation of the Minnesota concentrating mill that was then in the course of construction for treating the average grade of No. 8 siliceous chalcopyrite ore. After this plant

was completed, White held the position of mill foreman until 1919, when he left to join Burch and Hershey, taking Caetani's place as metallurgical engineer, and that firm became Burch, Hershey, & White.

Hershey devoted a great deal of time and study to working out the details of the Iron Mountain geology. He retired in 1927; however, Albert Burch continued to serve, combining the duties of the three former members of the firm, until his death in October, 1943.

J. M. Basham succeeded Burch as consulting engineer in January 1944, and is still serving in that capacity (1946).

Basham graduated in mining engineering from the University of California, and, after some practical experience in Utah, started to work for the company at Iron Mountain as a surveyor in January 1914. He very quickly demonstrated his ability and sound judgment, going steadily forward during the next 30 years from one important position to another. At Iron Mountain, following the first period as a surveyor, he was construction engineer, flotation-mill superintendent, cyanide-plant superintendent, assistant general superintendent, and also general superintendent at the Big Canyon mine in El Dorado County, which was owned and operated by the company. Finally in January 1944 he resigned to practice his profession as consulting engineer.

In solving many important problems, Basham rendered most valuable aid; but outstanding was the experimental work of 1928, for which he was largely responsible, and which resulted in the erection of a plant for treating the Iron Mountain gossan by the cyanide process. Likewise, he rendered yeoman's service in designing this plant, and in perfecting the mechanical details as well as the metallurgy, after it was in operation. Basham rendered another commendable service when he cooperated wholeheartedly in working out the flow sheet and in the preparation of the detailed drawings for the construction of the 350-ton daily-capacity flotation mill to treat the very complex sulphide of the Mattie ore body.

Personnel at Iron Mountain

James L. Richardson was a "hold-over" from the Sallee-Camden-Magee ownership. He was a sawyer and operated the small sawmill at Iron Mountain until it was destroyed by fire in 1897. Previously he had supervised the operation of the silver mill, which also burned in 1897. Later, in January 1900, he became the sheriff of Shasta County.

Alex Patterson and *John Swanson* were inseparable "buddies" who were originally employees of James Sallee. They continued with the company as stationary engineers as long as the upper powerhouse at Iron Mountain was operated by steam. Later they served in various capacities up to the time of their demise which, in the case of Patterson was the result of a false step on the old curved railroad bridge spanning Boulder Creek; he was precipitated into the deep gulch.

William Holliday, commonly known as "Scotty," was employed at Iron Mountain for many years as butcher and janitor, but specialized in gardening, mainly around the superintendent's house. He probably arrived about 1906, but the exact date is uncertain. He left in the early thirties and is reported to have died shortly thereafter.

Mine Superintendents

Gilbert McM Ross, 1895; W. H. Freeland, 1895-96; F. E. Willson, 1896-98; Hancock, 1898-99; T. C. Archer, 1899-1901; Selkirk, 1901; W. S. Haskins, 1901-02; Charles F. Nourse, 1903.

As can be seen from the above list, during the first few years of the company's operation at Iron Mountain, the mine superintendents followed each other in rapid succession.

Mine Foremen

Tonkins, 1895; Richard Roberts, Sr.; Jack Frigens; Sam Rosevere; L. C. Monahan; J. J. Shaw; Joe Griffen; George Williams; Alanzo Jacobs; M. J. Murphy; Hans Berg; Richard Roberts, Jr.

The record concerning mine foremen at the Iron Mountain mine is somewhat uncertain, but apparently when the development work started in 1895, Tonkins was foreman and Richard Roberts, Sr., acted as his assistant. Later Mr. Roberts became foreman.

L. C. Monahan, after leaving Iron Mountain, was first foreman and then mine superintendent at the Mammoth mine, near Kennett.

J. J. Shaw helped develop the plenary system for controlling mine fires; in 1905 he applied this method at the United Verde mine in Arizona.

Engineers and Mine Surveyors

Charles F. Nourse; James J. Murray; George Gray; D. F. Campbell; A. R. Motz; L. Hunt; W. C. Hammett; William Norsworthy; E. L. Stenger, 1910-14; A. W. Frolli; Charles S. Haley; A. de Gehardi; E. W. Blades, 1918-19; J. D. McPherson, 1922-24; William Eberth, 1928-30; J. G. Huseby, 1930-34; L. C. Raymond, 1934-36; R. K. McCallum, 1936-43; P. S. Pate, 1943-44; M. E. Harris, 1943-46; P. P. Kraai, 1944-45; T. P. Bagley, 1944-46; W. A. Guinan, 1946.

The data available are rather vague with regard to the exact dates and length of service of the various engineers who were employed at Iron Mountain prior to 1910, but subsequently the order of their succession is that given below. E. L. Stenger started to work at Iron Mountain in January 1910, and continued until March 1914. When he left, Frolli, Haley, and de Gehardi followed him in rapid succession. In the intervals between the employment of the last-mentioned three, as well as in the period between May 1, 1919, and William Eberth's arrival in 1928, J. M. Basham took on the mine surveying in addition to his other dutes.

P. P. Kraai joined the engineering staff in January 1944 and served until November 1945, when he resigned. T. P. Bagley took charge of the engineering office in May 1944 and remained in that position for the next two years, after which he acted as shift boss in the Hornet mine until August 1946, when he became foreman. W. A. Guinan, who was with the company as an assistant engineer for a short time prior to World War II, returned in April 1946 and in August was appointed to succeed T. P. Bagley in charge of the engineering.

D. F. Campbell, a graduate of the Royal School of Mines, was employed in the engineering department at Iron Mountain in 1904 and 1905. His work was most excellent, but he did not remain very long. However, before he left, he completed the so-called "Wiley map," which outlined the position of the ore bodies, so far as they were known at that time, and indicated their approximate tonnages. This map was prepared

in connection with some negotiations with the American Smelting and Refining Company who investigated the property, presumably with the idea of purchasing. During 1906-07, Campbell wrote a series of articles for the Mining and Scientific Press, which are well worth reading by anyone particularly interested in further details of the Shasta County copper belt.[7]

After leaving the company, Campbell became associated with H. H. Noble at the Heroult electric smelter, and in 1909 in a letter from Sweden, he wrote that he was making pig iron commercially by the Heroult process.

Edward L. Stenger came to Iron Mountain as a surveyor in January 1910, at which time the incline shaft in the No. 8 mine had reached the 280-foot level, and the lateral development had been started. His first work was to survey the No. 8 workings. Later he made a triangulation survey and a topographic map of the area between Slick Rock and Boulder Creeks. This was a real task and involved 2 years of strenuous work; but it proved to be of considerable help to Oscar H. Hershey when he began his geological studies in 1914. Another survey that required much of Stenger's time was an alignment map and profile of the Iron Mountain Railway. This was demanded by the State Railroad Commission to replace similar data lost in the San Francisco earthquake and fire of 1906.

In March 1914, Stenger left to take a position as a geologist with the Sissert Mining Company in the Ural Mountains of Russia. He came back to the United States in 1916, and in 1918 was re-employed as assistant to M. J. Murphy; but in the spring of 1919 a sudden slump in the price of copper closed the No. 8 mine, and Stenger went to Rochester, Nevada, for the Rochester Silver Mines. However, in 1919, at the request of M. J. Murphy, he returned to Shasta County and was stationed at Keswick in charge of the shops and narrow-gauge railway. He resigned in April 1922, upon the completion of the aerial tramway.

Ernest O. Blades entered the service of the company in the fall of 1916. He started as an electrician's helper in Charles J. Skendle's department, but shortly afterwards changed to a job as a machine miner, under mine foreman Hans Berg, with whom he had worked in a similar capacity in Arizona some 6 years before. Subsequently, in 1917, for a few months, Blades acted as assistant surveyor for Basham, but there was an interval, previous to Basham's departure in March 1918 to join the armed forces, when he resumed his underground work; this time as shift-boss, first in the Complex, then at the Confidence, and later at the No. 8 tunnel level. After Basham left in March 1918, Blades took over as mining engineer, under superintendent M. J. Murphy, and until he left in May 1919, was responsible for all surveying and mapping.

Blades' engineering work was characterized by great care and accuracy, but, unfortunately, in the period immediately following World War I, the conditions in the mining industry did not offer scope for his obvious ability; with the result that he evidently felt it necessary to seek "greener pastures."

[7] Campbell, Donald F., The iron ore of Shasta County, California: Min. and Sci. Press, vol. 93, p. 603, 1906. Campbell, Donald F., The copper of Shasta County, California: Min. and Sci. Press, vol. 94, pp. 28-30, 55-58, 1907.

R. K. McCallum joined the company's ranks in July 1935, as assayer helper at the cyanide plant. He continued in this capacity for only a little over a month when he was promoted and put in full charge of the assaying. In April 1936 he was transferred to the engineering department as assistant to L. C. Raymond and some 6 or 7 months later took full responsibility for the engineering. This situation continued for the next couple of years, or until June 1943. Upon the completion of the Mattie mill, he was again transferred and made assistant mill superintendent under E. M. Bagley, and subsequently, at the time of Bagley's illness in June 1945, McCallum was appointed mill superintendent. He is still serving as such (1946).

Catering Department

Arthur Wise, 1897; Harry Roberts, 1898-99; James Mackenzie, 1900; W. D. Egilbert, 1901-04; Andrew Macdonald, 1905; Finlay Northcutt, 1906-08; C. Hopper, 1909-37; B. W. Moorhouse, 1937-46.

In addition to the catering department at Keswick, a similar business was carried on at Iron Mountain, at first under the supervision of the smelter office, but on an independent basis after the smelting operations ceased at Keswick.

The men in charge of this department changed from time to time, but, beginning with 1897, the above list gives the names and approximate dates of service.

Electrical Installations

At Keswick: Arthur Dean, 1896; Edward Grant, 1897; Charles Newton, 1898-1900; James McDonald, 1900-03; William Bray, 1903-04. At Iron Mountain: William Forbes, 1905-12; J. C. Skendle, 1912-20; M. L. Poff, 1920; L. J. West, 1920-25; Chester Whitehead, 1925-26; Fred Orndorff, 1927-41; Duncan L. King, 1941-42; A. L. Pendry, 1942- .

The constantly increasing use of electric power in the company's Shasta County operations necessitated the employment of men with special technical ability to supervise the widespread electrical installations. In the order of their succession, these men were as noted above, but the dates are not exact.

Duncan L. King was originally employed by the San Francisco Chemical Company, a subsidiary of The Mountain Copper Company, as a mucker, miner, and surveyor, at the Waterloo phosphate mine, near Montpelier, Idaho. This was during the summers of 1928, 1929, and 1930, as well as the summer and fall of 1931. After graduating from the University of Wyoming, in the fall of 1931, he was transferred to Iron Mountain, where for about a year and a half, he served as laboratory assistant. This was followed, in August 1933, by an appointment to the position of assayer and assistant superintendent of the cyanide plant, and later, shortly after the death of M. J. Murphy, the general superintendent, in August 1935, he became mill superintendent in full charge of the cyanide plant. He continued in this position until April 1942. In the meantime, beginning in March 1941, in addition to supervising the mill, he acted as chief electrician for all of the company's Shasta County operations.

King resigned in April 1942, and until July 1945 held a position as mill superintendent at the Gray Eagle copper mine in Siskiyou County; but upon the closing of that property he was re-employed by the com-

pany and appointed superintendent of the Waterloo mine in Idaho, where he is still in charge (1946).

Keswick Personnel

Smelter

Smelter superintendents: W. H. Freeland, 1896-98; J. W. Bennie, 1898-1901; A. S. Haskell, 1901-04; T. J. Jones, 1904-07.

Herbert Lang. In 1895 Herbert Lang, a consulting metallurgist employed by the company, suggested the use of the pyritic-smelting system at Keswick, and conducted some experiments with pyritic smelting. The experiments were not successful. Upon the advice of H. A. Keller, however, a blast-furnace plant was erected. In spite of some preliminary discouragement, trials were continued by J. W. Bennie; but it was during A. S. Haskell's time that the details were perfected and pyritic smelting of Iron Mountain sulphide ore was established on a practical basis. T. J. Jones, as general superintendent, continued the smelting on a comparatively small scale until 1907, when the Keswick plant was abandoned.

J. W. Bennie was sent from England in the autumn of 1897 and started his work in the Keswick laboratory as research chemist in November of that year. He continued to serve as a chemist until he was appointed smelter superintendent in 1898. The records indicate that prior to March 1898 his experiments had developed the possibility of extracting a high percentage of the gold, from rather coarsely crushed Iron Mountain gossan, by dissolving it in a weak solution of cyanide. However, it was not until 30 years later that a plant was built to apply this process.

Bennie continued in charge of the smelting until the beginning of 1902, when he resigned to take a position as superintendent of Cananea smelter in Mexico. Subsequently, about the middle of 1903, he went to Arizona as general manager of the Commercial Copper Company at Clifton.

A. S. Haskell was first employed by the company in May 1899 to take charge of certain new construction work. At that time Thomas Neilson was superintendent of calcination, but within a year he resigned, and Haskell was appointed to his place. When J. W. Bennie resigned his position of smelter superintendent in 1901, Haskell succeeded him (February 1901), holding the position until the latter part of 1904, when he was transferred to Martinez, California, to supervise the erection and starting of the company's new plant.

Smelter foremen: Gus Noldi, 1896-1901; Jack Chapman, 1901-02; Jack Fisher, 1902-07.

Gus Noldi. The first foreman of the Keswick smelter was Gus Noldi, who came from Butte, Montana, about the middle of 1896 and left in February 1901 to join Freeland in Ducktown, Tennessee. He was a splendid blast-furnace man, and he must be given much of the credit for the successful furnace work at Keswick.

Jack Chapman was smelter foreman at Keswick from February 1901 to almost the end of 1902. He was an exceptionally good blast-furnace man.

Jack Fisher succeeded Jack Chapman as smelter foreman at Keswick, and remained until the smelter was finally closed. He too was an exceptionally good man.

Laboratory

When the Keswick smelter first began operating, Thomas Neilson was head of the laboratory, but early in 1897 he was put in charge of the calcining department where he remained until Haskell took over the work in 1902.

W. B. Rountree became chief chemist when Neilson was transferred to the calcining department and with him were associated from time to time a number of others, including John A. Balch, J. W. Bennie, Clarence Grabill, C. W. Dunbrow, Donald Frazier, J. O. Weinstrom, B. L. Moore, and Stafford Kirkpatrick. Also there were four young college students, employed as apprentices. Balch, Bennie, Grabill, Rountree, Weinstrom, and Moore were all outstanding men and were employed for many years; in fact, Moore was still working for the company at the time of his death.

John A. Balch came with the company early in 1896, his first work being in the laboratory as assistant under Thomas Nielson, who was chief chemist at that time. Balch continued in the laboratory for several years, but was especially interested in smelting metallurgy and, at intervals when the smelter superintendent happened to be absent, would substitute for him. This was during the incumbency of Bennie and Haskell, as well as for a short time after Haskell was transferred to Martinez. However, Balch was never appointed officially as smelter superintendent at Keswick. In 1905 he did some field work for the company in Idaho, and on his return to California he was put in charge of the reverberatory copper smelting plant at Martinez, which he conducted most successfully until 1908, when he resigned to go into business in the Hawaiian Islands. Balch was a most faithful and competent employee, well liked by the management and his fellow staff members.

J. O. Weinstrom came to Keswick about 1898 or 1899 and was employed as a sampler. Subsequently, after an interval as timekeeper, he was transferred to the laboratory, where he remained until the operation of the Keswick smelter ceased, after which he was employed at the Martinez plant for a short time. Then, from 1906-08, he represented the company in Nevada, buying and shipping siliceous gold and silver ores from Tonopah and Goldfield. He continued to serve the company in various capacities until 1912, when he resigned to go into the insurance business.

Hospital Staff

In 1895, Dr. Milliken was sent from London to take charge of the company's hospital, but he resigned during the first part of 1897, shortly after Lewis T. Wright's arrival. A Dr. Drake was appointed by the directors in London to succeed Dr. Milliken, but he remained only a little more than a year, and was followed by a local man, Dr. Davidson, who also quit within the year. Next came Dr. Chester Taess, who managed to stick for 2 years, after which Dr. George W. Sevenman took over until about 1915. Dr. J. C. Cummings was associated with Dr. Sevenman for a few months, but evidently the position of mine doctor did not appeal to him, because he left soon after Dr. Sevenman. The next resident physician was Dr. J. E. Taylor, who finally left in 1919 to take up private practice. By this time a good hospital was available in Redding, which, coupled with the ease and promptness of transportation, made unnecessary the maintenance of a hospital.

Accountants

R. N. Trueman, 1895-98; H. D. Campbell, 1898; William Read, 1898-1901; W. S. Howard, 1901-41; G. N. Mensor, 1941-.

R. N. Trueman. In 1895 R. N. Trueman became the first accountant at Keswick, and, for a short time after Ross resigned from the position of general manager, H. L. King, who had previously been payroll clerk and timekeeper at Iron Mountain, was transferred to Keswick as Trueman's assistant.

H. D. Campbell. In 1898 H. D. Campbell succeeded to the position of the head of the accounting department, and Trueman was transferred to the catering department. When Trueman resigned as head of the catering department in 1898, Campbell succeed him; Campbell held this position until October 19, 1900, when he and George Bridge met a tragic death by drowning in Rock Creek. Both men had attended an Odd Fellows ball in Redding. The following morning they were driving back to Keswick with Campbell's horse and buggy, which he maintained for his own pleasure, but heavy rains had fallen during the night, converting Rock Creek into a raging torrent, and, when they attempted to cross at the usual ford, the swift current overturned their conveyance and carried them down stream. The horse broke loose, gaining the bank after going a little more than 50 feet. Bridge's body was recovered within 1,500 feet of the crossing, but Campbell was swept on into the Sacramento River and his body was not found until 2 weeks later, just below Redding. George Bridge was an Englishman and had been the timekeeper. Campbell was a Scotchman sent from London in 1896. Both were fine men and their loss was keenly felt by the other members of the staff.

William Read. The post of chief accountant next fell to William Read, an Englishman who came from London in 1898. He left in 1901.

W. S. Howard. In the summer of 1900, W. S. Howard was sent from London, nominally to act as Read's assistant, but really preparatory to taking the position as chief of the accounting department, which duties he assumed in 1901. Howard continued in charge of the company's accounts until June 1941, when he retired on account of ill health. He died November 15, 1941.

G. N. Mensor succeeded Howard as chief of the accounting department, and still continues in that position (1946).

Catering Department

Managers: R. N. Trueman, 1896-98; H. D. Campbell, 1898-1900; Harry Roberts, 1900-03; Jesse Bell, 1903-07.

The general store, or "catering department", was established at Keswick in 1896, under the management of R. N. Trueman, who was transferred from the accounting department, of which he had been the head. He resigned in 1898 and was succeeded by H. D. Campbell, who had previously succeeded him as chief accountant. When Campbell and George Bridge were drowned in Rock Creek in the late fall of 1900, Harry Roberts, who had served as assistant to Campbell, took his place. Roberts remained until 1903, and was followed by Jesse Bell, who continued as manager of the catering department until the smelter was closed down.

Office Staff

H. P. Mudd, 1895-1946; Clement Hooper, 1895-1937; Harry Alger, 1896-1938; F. O. Hurt, 1899-1931; Charles F. Reed, 1900-46; Harry Davidson, 1900-20; James Bass (at intervals), 1900-19; B. W. Moorhouse, 1906-46; Fred Lanyon (at intervals), 1915-46; F. L. Richardson (at intervals), 1910-46.

In addition to the regularly appointed accountants, there were a number of clerks and timekeepers at both Keswick and Iron Mountain, but, due to the fact that living conditions at Keswick were particularly unpleasant and because Iron Mountain was an isolated camp, there was considerable turn-over at both places. In fact, many employees remained only a few weeks, or at most for a year or two. However, there were a few of outstanding ability that started in subsidiary capacities and were promoted to responsible positions, which they held for many years. Some of the early office staff, with records of long and continuous service, are listed above.

On the other hand, some of the especially competent men could not resist opportunity where life appeared to be better. Two of these were clerks in the Keswick office, namely W. C. Renwick, who followed Freeland to Tennessee, and E. L. Williams, who joined Bennie at the Commercial Copper Company in Clifton, Arizona.

H. P. Mudd was one of the very early employees, engaged shortly after Cole in the autumn of 1895. His first job was as timekeeper and, because of the grading on the railroad and construction work then in progress, he had to make the rounds twice each day, partly to see that the men were really working and to pay off such as wanted to quit. This often involved walking to Minnesota and back (a matter of about 10 miles) and meant 12 hours work at least. Incidentally, there was no limit of 8 hours on a day's work at that time.

In 1898, Mudd was placed in charge of the Iron Mountain office, where he stayed for several years. He was finally transferred, first to Keswick, and then to the Martinez plant, as office manager and statistician. He has continued at the latter point to the present time (1946).

Clement Hooper started work for the company in Shasta County in a clerical position, on July 15, 1895, and continued in this service for 42 years until he resigned in 1937. During the early portion of this period he was located at Keswick, but in 1901 he was transferred to Martinez where he remained until 1908, after which he returned to Shasta County and was in charge of the accounting office and the company's store at Iron Mountain.

Harry Alger was another "old-timer" who acted as storekeeper. He was first employed in August 1896, and did not retire until March 1938, after the destruction of the company's Iron Mountain store.

F. O. Hurt joined the company's staff in the autumn of 1899 as private secretary to Lewis Wright. He had formerly been connected with the Southern Pacific Company and the knowledge he had acquired of railroad rates and other business proved of special value to the company and enabled him to handle much of the office detail at Keswick. When the company's executive office was transferred to San Francisco in 1904, Hurt accompanied Wright and continued to act as his secretary,

besides dealing with various routine matters, including purchases and sales. On account of ill health he was compelled to retire in 1931.

Charles F. Reed started his work with the company about 1900. He worked a few months under Hoffman, who was chief engineer, and was then transferred to the hardware store, under C. Hooper, purchasing agent, where he remained for over a year. He was then given the job of night dispatcher by W. L. Cole, who at that time was superintendent of the Iron Mountain Railway. Reed held this, the train-dispatching job until 1903, when he became timekeeper. Following this, there was a period of office work, coupled with some train dispatching, until the removal of the Southern Pacific Railway connection from Keswick to Matheson in 1922. Due to his exemplary work at Keswick, he was appointed traffic manager at Matheson, a position which he still holds.

Harry Davidson arrived in Keswick about 1900 and his first job was as steward in the messhouse, but he was very soon promoted to the post of railway scale-weigher and train dispatcher. After a few years he was sent to Iron Mountain where he acted as warehouseman and superintended the loading of the ore trains and their dispatching from the mine. Davidson left shortly after 1920 and moved to the San Francisco Bay area with the idea of securing better educational facilities for his children.

B. W. Moorhouse, a native of Sheffield, England, decided in 1905 to try for "fame and fortune" in California; shortly after his arrival he was given a trial in a clerical capacity in the company's San Francisco office, but his unfamiliarity with the geography and customs of the country rendered his services of little value. The outcome was that, after a week or two, he retired, and obtained employment in the office of a San Francisco iron foundry. Previous experience in a steel foundry in Sheffield evidently qualified him, at least to some extent, and apparently he gave satisfaction, retaining his job until the earthquake and fire of April 18, 1906, destroyed the iron foundry. This left him stranded and, in dire straits, he appealed to the assistant manager, who sent him to the company's Martinez plant. Here the superintendent put him to work as a weigher on the charge floor of the reverberatory copper furnaces. This was one of the most disagreeable assignments imaginable, involving constant exposure to dust, heat, and sulphur gases; but it served to demonstrate Moorhouse's ability to "stand the gaff," which was recognized by a transfer to a clerical position in the Martinez office. Subsequently, in 1909, he accompanied W. L. Cole to Iron Mountain, where he continued to serve well and faithfully until his retirement in September, 1946.

Fred Lanyon started work in June 1915, and has been in the company's service approximately 28 years. His first task was in connection with the precipitation of copper from the Hornet mine water, but he has worked in a score of other occupations, the last being that of warehouseman, both at Iron Mountain and at the Hornet mine. Whatever Lanyon has undertaken he has done well. He is still in service (1946).

F. L. Richardson is the son of James L. Richardson, who was employed at Iron Mountain when the Mountain Mines, Ltd., acquired the property in 1894. F. L. Richardson's first work for the company was on the Iron Mountain Railroad, from March 1910, to December 1911, when

he held in succession the jobs of fireman, brakeman, and conductor. He then left to take other employment. He returned in 1925 and has worked since continuously, in the following capacities: Carpenter's helper, hoistman, warehouseman, timekeeper, and cashier. He is still acting in the last mentioned capacity (1946).

Early-Day General Works Foremen and Mechanics

Fred Wise, master machinist (shops and foundry), 1895-1905; C. E. Mowdy, locomotive machinist on up-keeps, 1897-1905; Fred Goodspeed, smelter up-keep man, 1897-1904; Thomas Craze, head boilermaker, 1895-98; George Stafford, foundry foreman, 1897-1905; Frank Moulter, pattern-maker, 1897-1905; Charles Murchison, carpenter foreman, 1896-1905; Maurice Flynn, deputy sheriff and plant watchman, 1896-1905; Edward Lamus, trainmaster and yard foreman, 1896-1918; Patrick Dineen, track foreman, 1895-1920.

All of the above men were of the same type, great workers and good fighters and, in an emergency, would work right through for many hours until the job was finished. Thomas Craze, who left the company in 1898, followed Freeland to Tennessee; Murchison, who was an exceptionally able man, was transferred to Martinez in 1905, where he erected all of the buildings; Flynn also was transferred to Martinez, where he was employed until his death, about 1909.

Edward Lamus was employed by the company early in 1896, first as an operating trainman on the Iron Mountain Railway. Within a short time he was promoted to the position of trainmaster and yard foreman at the Keswick smelter. Physically he was a powerfully built man, and an indefatigable worker. In the case of a break-down of any kind or an emergency on the railway, he would stay on the job continuously, night and day, until the repair was completed or the difficulty overcome. When it became obvious in 1918 that within a few months all activities at Keswick would cease, Lamus resigned. During the latter part of his life he was connected with the potash industry in Utah. He died in July 1946.

Patrick Dineen was an ex-employee of the Southern Pacific Railway who specialized in track work, and in this connection acted as foreman on the construction and laying of the rails on the Iron Mountain Railway. He arrived at Keswick during the latter part of 1895 and after the road was completed, he was retained on maintenance work at Keswick for a time. About 1898 he was transferred to Minnesota where he made his headquarters for the next 4 years. He then returned to the Keswick railroad yards until 1904, when his services were required to lay the industrial tracks at the company's new Martinez plant.

Both at Keswick and Martinez there was a mile or more of track consisting of three rails, that is, a combination of broad and narrow gauge, and Dineen was an expert in laying and maintaining his three-rail system.

Hornet Mine

Mine foremen: D. McLennen, 1907-; L. E. Beck, 19 -11; R. D. Murphy, 1911-42; M. E. Harris, 1943-46. Mine superintendents: C. W. McClung, 1942-46; T. Paige Bagley, 1946-.

The extracting and shipping of pyrites from the Hornet mine began in the latter part of 1907, at which time D. McLennen was foreman under the general superintendent, T. J. Jones. McLennen left to take

a position as superintendent of a mine at Ione, California, and was succeeded by L. E. Beck, who continued as foreman until 1911, when R. D. Murphy replaced him.

After Murphy retired in 1942, C. W. McClung became mine superintendent, in which capacity he served until his appointment as general superintendent in August 1946, when T. Paige Bagley took over the supervision of the underground work. M. E. Harris, who had been engaged in August 1943 as mine surveyor, was within a short time transferred to the Hornet mine, where he worked as mine foreman under McClung. He resigned in February 1946.

R. D. Murphy was among the company's first employees. He worked as a machine miner on the Iron Mountain development from January to April 1897, when he left. He was employed elsewhere until December 1903, when he returned. During 1904 he undertook some underground contracting, after which he again left and did not come back until May 1909. Development was in progress at that time in the No. 8 mine, and R. D. Murphy was given the job of night boss, except for a period of about 5 months when he acted as foreman. This was while his brother, M. J. Murphy, was recovering from serious injuries sustained in a fall down the shaft, due to a broken cable. In May 1911 R. D. Murphy replaced L. E. Beck as foreman at the Hornet mine and, with the exception of a few months in 1930 when he was employed in the gossan quarry at Iron Mountain, he continued in this position until March 1942, when he retired.

Other Personnel

Ernest Gordon was sent from London early in 1901 to act as assistant accountant and was second to W. S. Howard in the Keswick office. Subsequently he was transferred to the Martinez office, where he served a few years and then resigned.

C. C. Doyle was employed at Keswick in the latter part of 1914. His first work was of a miscellaneous nature in the railroad yard in the vicinity of the old smelter but, when the Minnesota mill started operating in 1915, he became train dispatcher, taking over some of the duties previously handled by Charles F. Reed. Then, when Edward Lamus left in 1918, Doyle took his place and continued in charge of the shops and narrow-gauge railroad until September 1919, when he retired because of ill health, and was succeeded by Edward L. Stenger.

Walter L. Penick came to the Minnesota mill in 1915 as an operator in the filter plant, and later became assistant foreman under Lloyd C. White.

The use of the Oliver filter in the flotation process was at that time in its infancy, and Penick's services were especially valuable in helping to solve some of the problems involved. He left late in 1916.

Victor H. Dahlgren took charge of the aerial tramway in June 1922, shortly after its completion, relieving Thompson, foreman of the Painter Tramway Company, who had operated the line until it was accepted by the company. Dahlgren's handling of both the operating and maintenance problems on the tramway for almost a quarter of a century has been most exemplary and the cableway is still functioning under his supervision (1946).

Earle M. Bagley first entered the company's service in March 1929 and shortly thereafter, upon the completion of the reerection at Iron Mountain of the Minnesota flotation mill, he supervised its operation until it was closed down in June 1930. Also he had charge of the washing plant, used for treating the filling from the original Iron Mountain mine.

The cyanide plant, for extracting the gold from the Iron Mountain gossan, was ready to run in December 1929 and the responsibility for this was added to Bagley's other duties, continuing for a little over a year. He left in March 1931 to accept a position as mill superintendent with the Benguet Consolidated Mining Company in the Philippine Islands.

In January 1943, in anticipation of an early completion of the Mattie mill, Bagley was engaged to take charge of that operation. He immediately conducted a series of metallurgical tests on the Mattie copper-zinc sulphides and later, as the work progressed, checked the details of construction. After the plant was finished in July 1943, he took control, but unfortunately, in 1945, due to ill health, was compelled to relinquish his position.

John Kobe started with the company in January 1929 and worked in various capacities during the construction of the Iron Mountain flotation mill and the cyanide plant, including about a year as a mechanic in the repair garage at Iron Mountain.

In 1931 he was promoted to the position of foreman at the gossan quarry, where he remained until the early part of 1942, when the gold mining operation was discontinued because of World War II.

Subsequently, Kobe's services were utilized during the construction and operation of the Mattie mill until he was transferred to Montpelier, Idaho, in September 1945. His experience as quarry foreman at Iron Mountain gave him a sound, practical knowledge of "strip-mining" and fitted him particularly for supervising the open-pit system of extracting phosphate rock used at Montpelier.

William Tinto arrived at Iron Mountain in October 1923 and, for the first 6 months, acted as surveyor helper under J. McPherson; but in March 1924 he was put on the maintenance crew at the Hornet crushing plant, from which time his work was largely along lines either of construction or plant upkeep. He proved to be a very competent and resourceful foreman and maintenance mechanic, and beginning in 1931 he acted in this capacity at the Iron Mountain cyanide plant, respectively under J. M. Basham, J. G. Huseby, and D. L. King, returning to the Hornet crushing plant just before the suspension of the gold-mining operation in February 1942, and continuing there until he took charge of a crew that dismantled the Big Canyon plant. Subsequently, until February 1946, he worked as foreman mechanic on the construction of the Mattie crushing and flotation plant. In February 1946 he was transferred to Montpelier, Idaho, in connection with the erection of a plant for crushing and pulverizing phosphate rock. He resigned in April 1946 to accept a position with the Simplot Fertilizer Company at its plant near Pocatello, Idaho.

William Applegate was one of the company's office staff at its refining works at Elizabeth, New Jersey, but in 1906 he was transferred to

the Martinez office. He retained this position for about a year, when he was sent to Keswick as head officeman under T. J. Jones, who was then operating one blast furnace and shipping the matte to Martinez to be converted into blister copper. This was the final smelting campaign at Keswick and at its close Applegate joined the staff of the Balaklala Copper Company at Coram, but, when this plant also suspended operations, he went to the Philippine Islands. Here he engaged in business, which was apparently quite lucrative. After some years he contracted a tropical disease and returned to the United States. He went to Reno, Nevada, hoping to obtain medical relief, but this hope was not realized, and he died.

August Tillman was first engaged by the company at Keswick as a carpenter in September 1895. He left 4 months later and did not return until 1902. Then he worked for about 6 years as a machinist in the Keswick shop, leaving to accept employment elsewhere. After his second return in 1915 he held the following positions: mine mechanic at Iron Mountain, 1915-18; machinist at the Keswick shop, 1919; foreman at the Keswick shop, 1920-22. In 1922 the Keswick shop was moved to the upper terminal of the aerial tramway at Boulder Creek adjacent to the Hornet mine, and Tillman continued as shop foreman at this new location from 1922-40, when he retired and was succeeded by A. R. Harrison. Altogether, Tillman served the company, in various capacities, faithfully and efficiently for more than 40 years, and many a time his unselfish efforts, skill, and hard work kept the ''wheels turning'' and prevented serious losses.

A. R. Harrison, who followed Tillman in 1940, as a very worthy successor, was employed by the company at Keswick in October 1919 in the joint capacity of locomotive engineer and machinist, but in 1922, after the operation of the Iron Mountain Railway was suspended and the Keswick shop was moved to the upper tramway terminal, he continued to work at the new location as chief assistant machinist until the time of Tillman's retirement in June 1940. Since then he has been master mechanic, first at the Boulder Creek shop and subsequently at the new shop erected in 1943 adjacent to the Mattie mill and the portal of the Richmond tunnel of the Hornet mine.

Robert J. Burgess, a very versatile mining engineer and a graduate of the School of Mines at the University of Minnesota, joined the company's staff in 1934. During the next 10 years, he served for a considerable time as assayer at the Iron Mountain cyanide plant but at intervals was sent out to investigate, sample, and, in some instances, to conduct the preliminary development on various properties in which the company was interested or had options. Also, certain special research problems were submitted to him, as well as the supervision and mapping of some of the exploratory diamond drilling in the vicinity of the Hornet mine. Burgess was a conscientious and methodical worker, never sparing any pains to obtain the correct answers on any questionable points. As a mine sampler, his work was especially commendable, because of its reliability. He resigned in December 1943 to accept a position as project engineer with the United States Bureau of Mines, with headquarters at Hanover, New Hampshire.

H. C. Vickery came to work for the company in July 1933, as a metallurgical assistant. He held various jobs in this department until April 1942 when he left for the armed forces. He returned, under army furlough, January 2, 1944, to be an assayer at the Mattie mine, which position he held until April 1946, when he left because of family illness. He returned in August 1946 to the engineering office where he is now serving as an engineer (December 1946).

S. G. Watson worked in the company's metallurgical department in the summer of 1941. He left in the fall to finish his college course, and went from the University of California directly into the Army Air Corps, where he served as a captain. He returned to The Mountain Copper Company as an asayer and metallurgist. In October 1946 he was appointed assistant mill superintendent, which position he now holds (December 1946).

L. J. Dickey was employed by the company in November 1935. He started in the assay office and metallurgical department, where he worked in various capacities until June 1941, when he left to return home prior to going into the armed forces. He served in the Medical Corps and saw active duty in France and Germany. He was discharged in February 1946, and returned to work March 1, 1946, as assayer, which position he now holds (December 1946).

In Conclusion

The preceding account of Shasta County personnel of The Mountain Copper Company, Ltd., covers only the most prominent of the executives and key-men whose services were invaluable in the working out of the company's various practical, technical, and metallurgical problems. There were many others who also served, and whose hard work and wholehearted cooperation was a decided factor in such success as the company achieved. Before closing this account a few words in commendation of the rank and file seem to be in order.

At the outset, in the workings at Iron Mountain, the miners were mostly Cornish and Irish; but within a few years they were pretty well replaced with Spaniards and Italians. These latter proved to be very satisfactory workers, and it turned out, as time went on, that it was an advantage to have two nationalities on the job, as each was inclined to challenge the accomplishments of the other. Generally speaking, the Italians were the more eager at this game and seemed more willing to face hazards, at which the Spaniards would hesitate. The Spanish miners did not like cold, wet conditions underground, and it was a frequent occurrence at Iron Mountain, when any of the Spaniards were transferred from the warm Old mine workings and given a job either in the No. 8 mine or sent over to the Hornet, after working a short time, they would ask to be sent back to the "hot mine", and, if their request was denied, they would quit. Many of these men of foreign birth came direct to Iron Mountain from their native countries, and formed small communities where their native habits and customs were continued. However, it did not take long to acquire enough English to understand the orders given by the foremen and shift bosses, and the men worked well and diligently.

Until the Iron Mountain mine became on fire in 1898, the underground conditions were neither difficult nor hazardous, but, for a period

of 10 or 12 years thereafter, the winning of ore from the original Iron Mountain ore body involved many dangers and much hard physical work. In some instances, blocks of sulphide ore were extracted where the temperature of the rock was too high to permit the hand to remain in contact. In fact, at times the ground was so hot it was thought advisable to wrap the dynamite in asbestos before placing it in a drilled hole preparatory to blasting. Even the temperature of the air, forced to the faces of the workings with powerful fans, was seldom less than 110 degrees Fahrenheit. Under such conditions, it was necessary for the men to work in relays, usually 10 or 15 minutes of strenuous exertion in the extreme heat, followed by a similar rest period in a comparatively cool underground chamber, where quantities of water were consumed in preparation for the next labor period. Only men in perfect physical condition could stand this strain. In addition, there was the constant fear of the sudden stoppage of the fans, which supplied the air under pressure to hold back the sulphur gas, produced by the slow combustion of the sulphide ore. The result of such a contingency was a race with death to reach the portal of the tunnel and gain the open air ahead of the killing fumes. Even a short exposure to these gases might result in a fatal attack of pneumonia.

This, then, is written in tribute to the loyal and faithful men who, in the interest of their employer, cheerfully bore the physical hardships of their daily tasks and staked their lives to insure the company's success. Space does not permit the naming of many of these, but a few examples will indicate their general character and stamina.

Antone Mellerio was originally employed in January 1901 and, except for a couple of years absence, he continued to work until 1926, when he decided the daily burden was more than he could carry. However, he retained his home at Iron Mountain, where Mrs. Mellerio kept a few boarders to aid in the family support, in addition to which their two sons, Carlos and Taglio, also employed by the company, made regular contributions. Carlo, the older son, started working for the company in 1905, at the age of 12, as a door tender at one of the portals to the Iron Mountain mine and, except for the duration of World War I when he served as a soldier on the fields of France, his services were practically continuous until his death in 1943. Taglio, the younger son, is still employed by the company (1946). There was also a daughter, ''Artie'', who married Jack Alger. The Algers have a son, Carl, who at the time of writing (1946) is 20 years old and still with the United States Navy. Carl represents the third generation of ''Iron Mountain Mellerios''. Mrs. Mellerio died in 1934. Antone survived her by about 8 years.

Marco Gheller, commonly called ''Dutch'', was another outstanding character. He specialized in difficult timbering and, if the ground was very heavy and the work most dangerous, ''Dutch'' usually acquired the job. He came with the company in 1905 and for 30 years was in continuous service. In fact, he has returned to Iron Mountain and been employed, at intervals in recent years, even as late as 1946.

Frank Massock was also a timberman who did specialty work and only retired after almost 40 years of faithful service. He is now deceased (1946).

Sabittini Salvatori, always called "Ninety", has worked for the company continuously since 1904. During the days of active fire fighting in the Iron Mountain mine, "Ninety's" job was to advance the water pipes and keep them close to the fires, or at least in a position where they would be effective. He proved to be a regular "fire-eater", and it was wonderful the amount of heat he could stand. He seemed to be a human salamander, and he had a helper, Marieo, who was also most efficient. Of recent years "Ninety's" employment has been less perilous, being confined mainly to acting as power-house attendant, assistant electrician, or doing miscellaneous repair jobs. He is still working.

Pete de Sarno. Indicative of the risks that the men would take is the case of Pete de Sarno, who met his death at the upper Hornet tram bunkers on July 12, 1912. Pete was alone when the accident occurred and no doubt was trying to dislodge suspended ore, which was often done. There was always a rope provided, suspended from above with the lower end down in the bunkers, which a man could grasp in the case of a sudden slide of ore. No doubt de Sarno became careless and neglected to keep hold of the rope. At the outset, there was no evidence he was under the ore but, not being able to find him elsewhere, a start was made to draw off the contents of the bin, when his body was found, but it did not appear to be badly crushed. The investigating jury did not hold the company to blame.

As a result of the naive nature of the Italian miners, some rather amusing incidents occurred. The following are characteristic.

On one occasion it became necessary to reduce the working force and a "share the work policy" was adopted, the men being laid off in turn. Within a few days a particularly industrious man appealed to the superintendent and, in very broken English, explained he had a large family and was without money to support them. The superintendent was puzzled, because this employee had been earning good wages for many months. Finally the direct question was asked, "What have you done with your money?" This brought a prompt reply, "Ah gota heem en da bank."

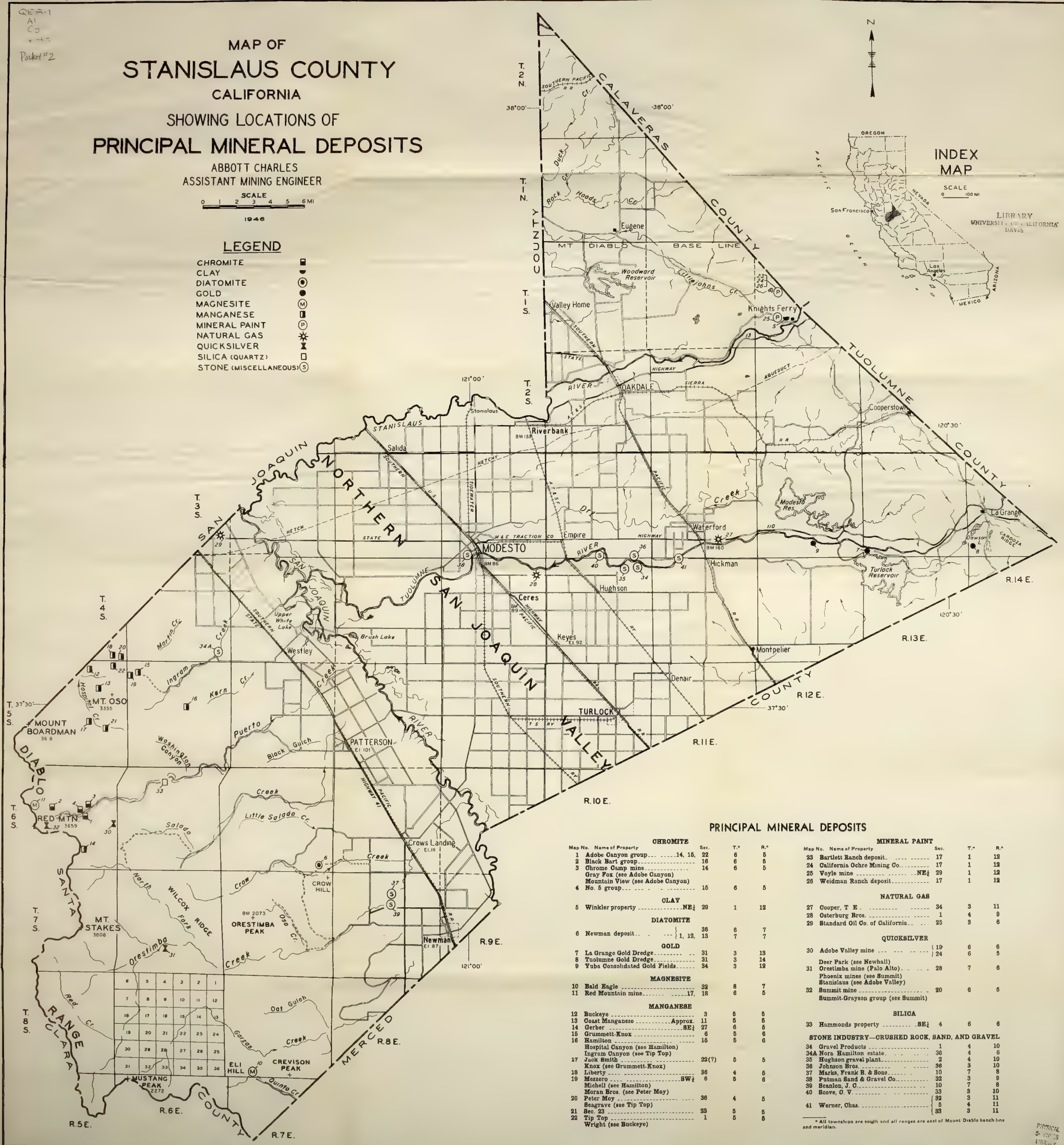
A little later this same man appeared on a very rainy morning and requested the superintendent to "fixie da house," explaining that the roof leaked, compelling him to "movie da bed all night."

Pete and Tony Gennari, brothers, were two old-timers, both of them exceptionally good miners, but Pete was inclined to take a few days off now and then and go on a lonesome spree. On one of these occasions he approached the company's doctor, saying he was sick and wanted something to make him well. The doctor told him, "Pete, if I were to give you something to sober you up and make you well, you would simply go back and get drunk again." Pete replied, "That's what I want Mr. Doctor, I not finished yet."

Grateful acknowledgment is made for the data contained herein to various members of the company's staff, but particularly to Mr. W. L. Cole, Sr., the former general superintendent, Mr. A. S. Haskell, the former smelter superintendent, Mr. J. M. Basham, the consulting engineer, Mr. J. G. Huseby, the present assistant manager, and Mr. W. D. Tillotson, who has been the company's legal representative in Redding since 1897.

o

71637 3-47 2000



PRINCIPAL MINERAL DEPOSITS

Map No.	Name of Property	Sec.	T.*	R.*
	CHROMITE			
1	Adobe Canyon group 14, 15,	22	6	5
2	Black Bart group	16	6	5
3	Chrome Camp mine	14	6	5
	Gray Fox (see Adobe Canyon)			
	Mountain View (see Adobe Canyon)			
4	No. 5 group	15	6	5
	CLAY			
5	Winkler property NE¼	29	1	12
	DIATOMITE			
6	Newman deposit	36	6	7
	1, 12,	13	7	7
	GOLD			
7	La Grange Gold Dredge	31	3	13
8	Tuolumne Gold Dredge	31	3	14
9	Yuba Consolidated Gold Fields	34	3	12
	MAGNESITE			
10	Bald Eagle	32	8	7
11	Red Mountain mine 17,	18	6	5
	MANGANESE			
12	Buckeye	3	5	5
13	Coast Manganese Approx.	11	5	5
14	Gerber SE¼	27	6	5
15	Grummett-Knox	6	5	6
16	Hamilton	15	5	6
	Hospital Canyon (see Hamilton)			
	Ingram Canyon (see Tip Top)			
17	Jack Smith	22(?)	5	5
	Knox (see Grummett-Knox)			
18	Liberty	36	4	5
19	Mezzero SW¼	6	5	6
	Michell (see Hamilton)			
	Moran Bros. (see Peter Moy)			
20	Peter Moy	36	4	5
	Seagrave (see Tip Top)			
21	Sec. 23	23	5	5
22	Tip Top	1	5	5
	Wright (see Buckeye)			
	MINERAL PAINT			
23	Bartlett Ranch deposit	17	1	12
24	California Ochre Mining Co.	17	1	12
25	Voyle mine NE¼	29	1	12
26	Weidman Ranch deposit	17	1	12
	NATURAL GAS			
27	Cooper, T. E.	34	3	11
28	Osterburg Bros.	1	4	9
29	Standard Oil Co. of California	25	3	6
	QUICKSILVER			
30	Adobe Valley mine	19	6	6
		24	6	5
	Deer Park (see Newhall)			
31	Orestimba mine (Palo Alto)	28	7	6
	Phoenix mines (see Summit)			
	Stanislaus (see Adobe Valley)			
32	Summit mine	20	6	5
	Summit-Grayson group (see Summit)			
	SILICA			
33	Hammonds property SE¼	4	6	6
	STONE INDUSTRY—CRUSHED ROCK, SAND, AND GRAVEL			
34	Gravel Products	1	4	10
34A	Nora Hamilton estate	36	4	6
35	Hughson gravel plant	2	4	10
36	Johnson Bros.	36	3	10
37	Marks, Frank B. & Sons	10	7	8
38	Putman Sand & Gravel Co.	32	3	9
39	Scanlon, J. C.	10	7	8
40	Scove, C. V.	33	3	10
41	Werner, Chas.	32	3	11
		5	4	11
		33	3	11

* All townships are south and all ranges are east of Mount Diablo base line and meridian.

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

OLAF P. JENKINS, Chief

Vol. 43	JULY 1947	No. 3

CALIFORNIA JOURNAL

OF

MINES AND GEOLOGY

STATE OF CALIFORNIA

EARL WARREN, Governor

DEPARTMENT OF NATURAL RESOURCES

WARREN T. HANNUM, Director

DIVISION OF MINES

OLAF P. JENKINS, Chief

Headquarters

Third Floor, Ferry Building, San Francisco 11

District Offices

State Building, 217 West First Street, Los Angeles 12

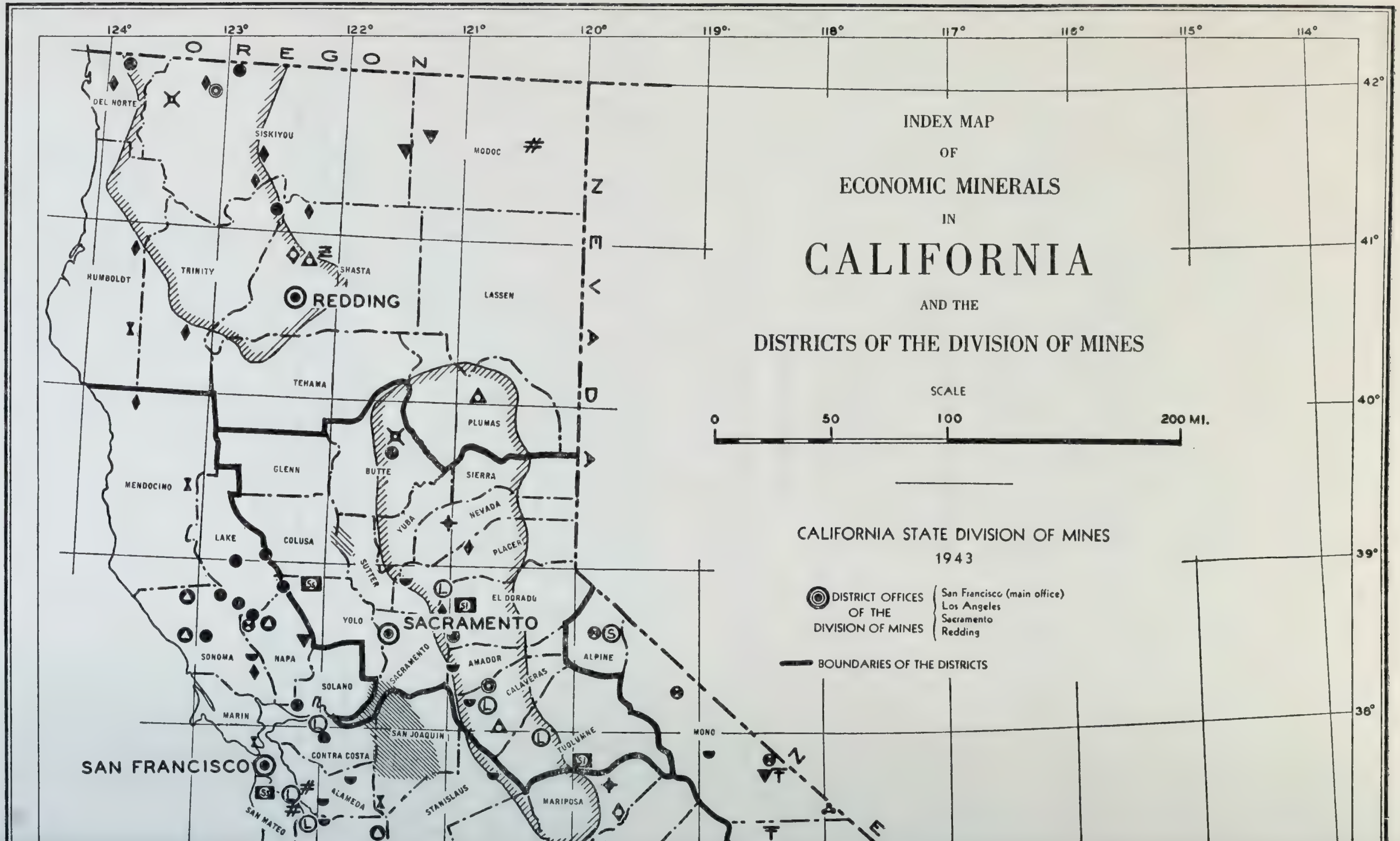
631 J Street, Sacramento 14

Box 445, Redding

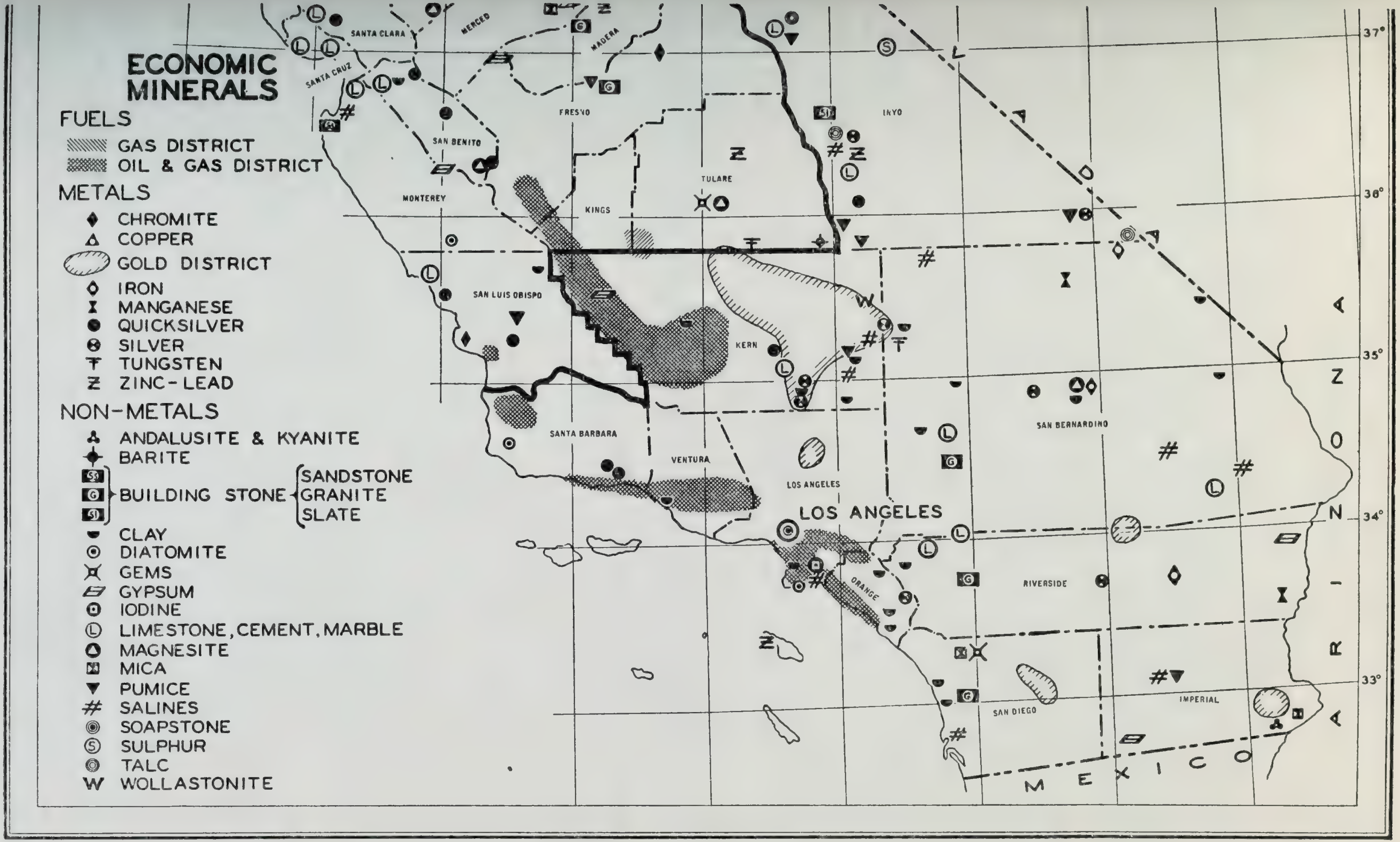
The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles and Sacramento district offices.

In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology and mining of California, is given to the public by means of publications, mimeograph releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines consist of the quarterly periodical **California Journal of Mines and Geology,** issued in January, April, July, and October of each year, and a series of **Bulletins.** Mimeographed **Information Circulars** and **Announcements of New Publications** are also released periodically. A list of publications will be sent free upon request.



INDEX MAP
OF
ECONOMIC MINERALS
IN
CALIFORNIA
AND THE
DISTRICTS OF THE DIVISION OF MINES
SCALE
0
50
100
200 MI.
CALIFORNIA STATE DIVISION OF MINES
1943
DISTRICT OFFICES OF THE DIVISION OF MINES
San Francisco (main office)
Los Angeles
Sacramento
Redding
BOUNDARIES OF THE DISTRICTS
OREGON
NEVADA
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
MENDOCINO
NEVADA
YUBA
LAKE
COLUSA
SUTTER
PLACER
EL DORADO
YOLO
SACRAMENTO
SONOMA
NAPA
AMADOR
ALPINE
SOLANO
CALAVERAS
MARIN
SAN JOAQUIN
MONO
TUOLUMNE
SAN FRANCISCO
CONTRA COSTA
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO


ECONOMIC MINERALS
FUELS
GAS DISTRICT
OIL & GAS DISTRICT
METALS
CHROMITE
COPPER
GOLD DISTRICT
IRON
MANGANESE
QUICKSILVER
SILVER
TUNGSTEN
ZINC-LEAD
NON-METALS
ANDALUSITE & KYANITE
BARITE
BUILDING STONE
SANDSTONE
GRANITE
SLATE
CLAY
DIATOMITE
GEMS
GYPSUM
IODINE
LIMESTONE, CEMENT, MARBLE
MAGNESITE
MICA
PUMICE
SALINES
SOAPSTONE
SULPHUR
TALC
WOLLASTONITE
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
FRESNO
INYO
SAN BENITO
MONTEREY
TULARE
KINGS
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
N E V A D A
A R I Z O N A
M E X I C O
37°
36°
35°
34°
33°

CONTENTS

STATUS OF TOPOGRAPHIC MAPPING IN THE UNITED STATES

PREPARED BY THE MAP INFORMATION OFFICE
UNITED STATES GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR*

A preliminary study of the present status of topographic mapping in the United States has been completed by the U. S. Geological Survey. One of the results of this study has been the publication of an index map on which are shown the areas covered by topographic maps published by the Geological Survey and other agencies. A copy of this map is enclosed (in pocket) with this issue of the Journal.

In California, topographic mapping has been carried on almost continually since 1880 so that now more than 85 percent of the state has been mapped in some manner. The quality of this work has varied greatly. At one extreme are the earlier surveys which were made very rapidly on a small scale. These maps are of little value for present-day engineering uses and many of them have been withdrawn from publication. At the other extreme are the modern maps which are drawn on larger scales and according to specifications required by present-day needs.

The maps of two notable areas in California are of particular interest. The Central Valley was mapped during the period 1903-32, and Los Angeles County was mapped during the period 1923-37. These topographic maps are of very high quality and the wisdom of those responsible for their preparation has been repeatedly demonstrated during the subsequent and extensive development of each of those areas.

Unlike much of the mapping which was done during this period, the maps covering these two areas were made on a comparatively large scale and according to very high standards of accuracy. Many of these maps are now being revised and restored to their full usefulness by the addition of new roads, buildings, canals, and similar man-made features. In addition to the revision program, much new mapping is being carried on in areas which either have never been mapped or were mapped on scales which are no longer considered adequate.

Topographic mapping in California has been greatly accelerated during the last two years as a result of the expanded program which the state is now carrying on in cooperation with the U. S. Geological Survey. In view of this manifest interest in topographic mapping, the recently concluded appraisal of existing coverage may be noteworthy.

On the accompanying index map of the United States, the extent of the topographic map coverage is shown. This listing includes only those maps which are, or soon will be, available for general distribution. It should be noted also that it is confined to topographic maps, no record of planimetric maps being shown.

More important than the coverage summary, however, is the classification of each map as to its relative quality. It has long been felt that the map user should be given some indication of the quality of each map which he may have occasion to use. The whole map appraisal problem is of such complexity and importance that it requires, and justifies, more attention than it has been given in the past. The appraisal presented

* Manuscript submitted for publication April 4, 1947.

is of a tentative nature since much work remains to be done in further clarifying standards of appraisal, studying the various requirements of map users, and critically examining each map upon the standards thus formulated. The Geological Survey considers this map the forerunner of a more comprehensive series of index maps on which will be shown such information as publication scale and the producing agency. Index maps may also be issued showing the areas covered by planimetric maps or topographic surveys which, although made for a special purpose, may be of general usefulness.

It will be noted that the maps published by the Geological Survey have been segregated into four categories. The maps of other agencies, however, have not been evaluated by the standards applied to the Geological Survey maps. This is because the interim standards, which were adopted to facilitate a rapid appraisal of the Survey maps, do not readily apply to the great majority of maps produced by other agencies. As a temporary expedient, pending the development of suitable standards and the subsequent work of appraisal, an evaluation made some months ago by the Corps of Engineers was used. This evaluation considered the map elements desirable for domestic use, and indicated the elements lacking in each map produced for emergency military needs. Those maps containing the elements and quality essential for general domestic use are therefore indicated as "of standard content" while those lacking certain elements are shown as "other usable maps." The various elements are described below in the explanations of standards employed in this preliminary study.

Maps which have been completely superseded by more recent surveys have not been shown on the accompanying index. It will be noted, however, that older Geological Survey maps are occasionally shown in addition to the later surveys of other agencies. This procedure has been followed wherever it appears that comprehensive map use would be benefited by reference to both maps covering a particular area. The usual case of this nature involves an older Geological Survey map of fairly good contour character and detail and a recent resurvey apparently of lower contour quality in whole or in part, though perhaps having up-to-date planimetry of higher quality than that of the older map.

The areas showing work in progress by the Geological Survey (yellow) include work actually under way or definitely scheduled for the immediate future. Surveys for which field work has been completed are shown in red even though editing or reproduction may still be in process. Projected or otherwise tentative undertakings have not been indicated; but the schedules of other agencies may contain some tentative proposals since available records did not always distinguish committed projects from mere proposals.

There follows a brief description of the general standards of appraisal employed in evaluating the Geological Survey maps. It will be noted that descriptive labels previously applied, such as "adequate," "usable," and "inadequate," have been abandoned in favor of epitomized descriptions of the map content, stated in terms of the additional Survey work which would be required to enable the map to qualify for the top grade, which meets the general requirements of the present day.

It should also be noted that the present tentative standards of appraisal have not been allocated to the national standards of map

accuracy. The latter standards can be successfully applied to topographic maps produced during very recent years by modern photogrammetric plotting instruments and adequate field completion surveys, as well as to older "engineering surveys" of large scale. When applied to older surveys of relatively small scale, however, they do not afford an index of the practical utility of such maps, which would show very low percentages of position compliance for contours and planimetry but furnish adequate terrain generalities for many purposes. Ultimately the map accuracy standards will eliminate the need for any other appraisals, particularly when the country is at last covered with surveys of relatively high quality. Meanwhile some index of practical map utility is needed and a general "point-of-view" must be developed for this type of evaluation.

SURVEYS MADE BY MODERN METHODS

Under the classification "surveys made by modern methods" are included maps produced by modern photogrammetric plotting instruments as well as those having rigidly controlled or photo-compiled bases with extensive and detailed stadia coverage of the culture, drainage, and contours. The majority of maps falling in this classification have been produced since 1920 but many produced prior to that time also qualify. Conversely, many maps produced since 1920 may fall in the lower categories. The 1920 criterion is by no means a definite line of demarcation but indicates the approximate beginning of a trend toward intensifying the Survey's standards of mapping, which varied in application with the requirements of state cooperating officials and other controlling factors.

As a broad premise, the quality of the "modern" map is such that the accuracy of the planimetry and topography could not be substantially improved unless a resurvey of larger-scale and smaller-contour interval were undertaken. While this class implies multiplex compilation or complete stadia coverage, barometric control of contouring, if confined to areas of 1 square mile or less, can be accepted when it is known that this work was carefully carried out with precise instruments and tied to the stadia network or multiplex base at frequent time and position intervals.

Authorship was not considered in this classification since the maps appropriate for the grade should have been produced under such rigid procedures that the personal equation was largely eliminated. This factor was considered, however, in making close decisions between the "older surveys" and "reconnaissance methods" groups.

CULTURE REASONABLY UP-TO-DATE

In general, maps of the top grade, which have been produced during the last 10 years, were placed in the group "culture reasonably up-to-date". Occasionally recent surveys were not included—whenever it was known that substantial cultural changes have taken place since the field survey or inspection. Conversely, surveys made a little more than 10 years ago might be included when cultural change was known to be of very limited extent, such as the construction of a few houses with no important road constructions or abandonments.

OLDER SURVEYS

The class "older surveys" includes maps having a planimetric base slightly inferior to that of the "modern methods" standards and/or having topographic data falling somewhat short of those requirements. Contours controlled by a network of stadia, supplemented by aneroid in small areas, or surveys well controlled by graphic triangulation, with "sketching" limited to small areas, were placed in this classification providing anticipated use requirements and other considerations did not indicate that complete resurvey would be required to meet present-day needs. The maps of this group would require more planimetric detail and/or more extensive stadia control of contouring to raise them to the "modern" classification. Their basic quality is such that a revision of culture could be applied with relatively minor adjustments to the drainage and contour plates.

Authorship was considered in making close decisions between this and the "reconnaissance" grade, for in earlier days, when less basic control and traverse of physical features were employed, personal skill was relatively more important as a factor influencing the map quality. The topographer's abilities to interpret and delineate the terrain character, estimate distance and slope for placement of minor features, and otherwise make the most of limited allotments of time and funds, varied considerably. Modern standards have practically eliminated the personal factor in view of the systematic coverage, by photogrammetric plotting instruments or planetable, which is now required. The topographer's skill and efficiency still affects the cost and quality of surveys, but not to the extent possible in the earlier methods of survey.

As a very general guide, the average standards of survey employed during the period from 1910-20, which were distinctly above the earlier reconnaissance procedures, were considered for this classification.

SURVEYS MADE BY RECONNAISSANCE METHODS

The "surveys made by reconnaissance methods" includes, of course, all Survey maps which fall short of requirements for the higher grades. For the most part, this class includes maps produced prior to about 1910 and those published at scales smaller than 1:62,500. Some high quality 1:125,000 scale maps, however, have been tentatively placed in the next higher grade. As indicated in the legend statement, the very early rapid reconnaissance maps have been withdrawn from publication and have therefore not been shown on the accompanying index. This, in effect, is the fifth classification which includes the oldest and lowest-grade surveys, most of which were published at the 1:250,000 scale. Not all of the 1:250,000 scale maps produced by the Survey have been withdrawn from publication, however. Consideration is being given to the republication of certain maps in this class which cover areas otherwise unmapped, particularly those areas which will not be reached by new surveys for several years or more.

MAPS OF OTHER AGENCIES

As stated heretofore, maps of other agencies have not yet been evaluated by standards similar to those applied to Geological Survey maps. This work is now in progress but will not be completed for some

time since collaboration with the various producing agencies in formulating standards and appraising, and other time factors are involved.

The Corps of Engineers appraisal, from which the present cursory classification was derived indicated those maps, produced for military requirements, which do not contain the following domestic use elements:

A. Public land lines not shown.
B. Contour interval too large, incorrect interval used, contours not completed or lack expression.
C. Accuracy of mapping insufficient or in doubt.
D. Revision work not field edited.
E. Drafting below usual standard.
F. Woodland not shown.

Elements A, E, and F, though usually included in the ''standard'' domestic maps, are not considered quite as important as elements B, C, and D. Maps having the B, C, or D designation were therefore excluded from the first class of maps produced by other agencies, and placed in the ''other usable maps'' category. It is felt that this tentative segregation, though leaving much to be desired, will be helpful to map-users until a more comprehensive evaluation is accomplished.

It is realized that the foregoing description of the current appraisal view-point would be augmented by finite definitions of such terms as ''rigidly controlled'', ''small areas'', ''limited sketching'', and many other expressions. The purpose at this time, however, was to achieve a rapid tentative appraisal by cursory inspection of the many maps involved and leave the long-term tasks of developing well-defined standards, and their application, to be accomplished at some future date.

LIMESTONE IN CALIFORNIA

By Clarence A. Logan*

OUTLINE OF REPORT

* District mining engineer, California State Division of Mines. Manuscript submitted for publication July 1946-July 1947.

ILLUSTRATIONS

ORIGIN OF LIMESTONE

Chemical Precipitation

The question of the origin of limestone (and dolomite) has been the subject of many interesting hypotheses and much investigation. These can be only briefly outlined here.

Primarily, it is a problem of relative chemical solubilities and chemical precipitation. The first dry land, or perhaps even preceding submarine volcanic activity, furnished the first calcium.

Müller has observed that the substances most completely removed from the silicates of the land mass by water are generally lime, magnesia, and iron oxide. These are believed to have dissolved in the water in the form of acid carbonates, which have been carried away to be precipitated elsewhere when they lost part of their carbon dioxide. Daly (09) believes that the early pre-Cambrian limestone and dolomite deposits, and also those of the early Paleozoic, were chemical deposits precipitated when ammonium carbonate was generated by the decay of soft-bodied marine organisms devoid of shells. This method of deposition, he thinks, became less important as the number of fishes and other scavengers increased in the ocean to the point where the evolution of ammonium carbonate was no longer a controlling factor. With this balance disturbed, calcium salts could accumulate in ocean water, and this would be accelerated also by increased land areas subject to erosion. The evolution of hard shells started in the Cambrian, and larger deposits of shell limestone are found in the Ordovician and Silurian rocks. Since then, marine limestones have been made chiefly from the hard remains of animals and plants.

Daly's paper is largely a discussion of the role of rivers in supplying different ratios and amounts of calcium and magnesium to the ocean, and the apparent correspondence in the ratio of calcium and magnesium in the pre-Devonian limestones with the ratio of calcium and magnesium in the waters of such rivers as the Ottawa, St. Lawrence, and Mississippi, which flow over pre-Devonian rocks.

With ancient ocean waters low in lime content, it would have been possible for the formation of ammonium carbonate to cause precipitation also of magnesium, forming dolomite or dolomitic limestone. Daly cites many analyses in support of his theory. He also calls attention to the fact that microscopic examination of type specimens from nearly 7000 feet of unmetamorphosed Cambrian and pre-Cambrian carbonate rocks exposed in the 49th Parallel section in the Rocky Mountains gave strong confirmatory evidence. They appear to be of neither clastic nor direct organic origin; and neither horizon nor distance from old shore lines affects the singularly monotonous grain sizes, which are of the same order as in crystals of calcite and dolomite known to be chemically precipitated (Daly, 09).

However, F. W. Clarke (24, p. 131) has pointed out that calcium bicarbonate is very unstable, and can be broken down to normal carbonate and free carbon dioxide by evaporation, by rise in temperature, and by mechanical agitation. The solubility of $CaCO_3$ in water also varies greatly with its physical condition, the amorphous carbonate being much more soluble than the crystalline form. Stream-borne carbonate has been deposited in the delta of the Rhone River, and according to Clarke (24, p. 132) crystalline limestone is now being deposited in the Florida Keys.

In warm surface layers of the ocean, a variation of 2° C. in temperature or a change from 3.2 to 3.0 parts per 10,000 of CO_2 in the adjacent air is enough to cause precipitation of 2 grams of $CaCO_3$ in 1 cubic meter of a saturated solution. Such a precipitation, due to loss of carbon dioxide and cooling, occurs in the formation of stalactites and stalagmites in caves, and in the deposition of lime sinter or tufa or travertine by springs, though algae are partly responsible in the latter case. With the exception of algae, to be mentioned later, these phenomena appear to be confined to shore-waters in the ocean, and in California, travertine deposits have proved important only in Contra Costa County. Chemical precipitation of limestones in lakes has also been commercially unimportant in California. This method of formation has been credited by Lawson (14) and others as responsible for the formation of minor deposits in the Berkeley region. The Quaternary lakes of that part of the Great Basin in California are notable for their content of mineral salts, but calcium carbonate is not one of the more plentiful of these. The water of Mono Lake has been analyzed and calcium was found to be only a minor constitutent of the total solids. The area of this lake is $85\frac{1}{2}$ square miles and its total content of mineral salts has been estimated at 245,020,200 tons, of which only 3,213,400 tons would be calcium carbonate. In the water of Owens Lake, calcium appears only as a trace. Sodium salts predominate in both. Numerous domes of tufa have been deposited in Mono Lake by warm and cool springs rising in or near the lake. Many of these deposits have been exposed by the lowering of the lake level. Some of these springs still deposit calcareous tufa, but others have ceased such deposition and furnish notably pure water.

Thinolite is the name given by Dana (32, p. 516) to the tufa deposits found about Mono Lake, and on a larger scale in northwestern Nevada. It occurs in ''layers of interlaced crystals of a pale yellow or light brown color and often skeleton structure.''

Organic Deposition

A great variety of marine organisms deposit calcium carbonate as a part of their vital functions. The most important are the microscopic Foraminifera and the polyps. Globigerina ooze is an ocean mud made up largely of the shells of a genus of perforate Foraminifera. It is estimated that the bottom of 53 percent of the Atlantic Ocean having depths between 1500 meters and 4000 meters, is covered by this mud. In the Pacific, especially near the Equator and west of New Zealand, there is estimated to be a total area of 30,000,000 square kilometers covered by such ooze. In the Challenger Report, in the section on deep-sea deposits, Murray Renard (91), gave the total area of Globigerina ooze as 49,520,000 square miles and its mean depth as 1996 fathoms. Quoted analyses of this ooze ranged as high as 92.54 percent $CaCO_3$ and averaged apparently over 64 percent $CaCO_3$. The organisms responsible for these immense deposits live in the upper layers of ocean water, and the percentage of $CaCO_3$ in the muds of the ocean bottom decreases rapidly as the depth of water increases, being less than 1 percent at 3500 fathoms. Chalk deposits are derived from the remains of Foraminifera and it is believed that most of the purer, high-calcium limestone is from the same source. No deposits of high-grade chalk have been reported in California.

The work of polyps in building coral reefs is much better known than that of the Foraminifera. Polyps require clear salt water ranging in temperature from 70° to 82° F. and the water supply must be changed constantly to keep up the required amounts of $CaCO_3$ and oxygen. These little animals live at a depth of not over 150 feet below the surface. The rate of growth of coral is reported to vary from 1 foot to 15 feet in 100 years, the latter being the maximum observed under very favorable conditions. When the reef is built high enough to emerge from the water, the waves break up part of it into sand, and this in turn will be partly dissolved and by re-precipitation will cement the remainder into a solid limestone showing organic remains.

Other sea organisms may be locally important as builders of calcium carbonate. On San Francisco Bay for example, a large Portland cement plant draws its supply of this material from the deposits of oyster shells and other marine calcareous remains which are dredged from the bay. These deposits after washing yield a product carrying 90 to 95 percent $CaCO_3$. On the Florida coast, shells of a small clam and other calcareous fragments have been cemented together by $CaCO_3$ precipitated from the sea-water, and form a rock known as coquina, which is used for building and road construction.

Many of these marine organisms show deposition of both calcite and aragonite, and local conditions such as temperature and depth of water are believed to be the determining factors. Calcite, being more stable, is more common.

Dolomite

The problem of the formation of dolomite and magnesian limestone is another very interesting phase of the evolution of carbonate rocks. The evidence uncovered by boring in a few coral deposits has been somewhat confusing. Coral as originally deposited contains usually only a minor amount of magnesium, while at greater depth borings have indicated a proportion of magnesium carbonate nearly high enough to make dolomite. Perhaps the most important agencies in the formation of magnesian carbonates have been chemical precipitation in sea water directly from ionized solutions which drew their magnesium from supplies brought in from the land mass by streams; and also by the action of sea water upon the coral limestone, with the removal of part of the calcium in calcite (or in the less stable aragonite) and substitution of magnesium for it. The name dolomite has been very loosely used in the United States. It is often applied to magnesian limestones which are mixtures of widely varying proportions of the two carbonates. The conditions under which such deposits are formed may well be different in some essential factors from those resulting in the definite chemical compound dolomite, $CaMg(Co_3)_2$ which contains 30.4 percent CaO and 21.7 percent MgO and has a specific gravity of 2.8 to 2.9.

Dolomite has been artificially produced in different ways by a number of experimenters. For those interested, there is probably no better summary easily available than that given by F. W. Clarke (24, pp. 565-580).

Algal Limestones

The importance of algae (commonly called seaweeds) as builders of calcareous deposits has come to be recognized in late years, and many

papers on the subject have been written. Comparatively little of this literature deals with deposits in California. Levi F. Noble (41) mentions briefly the markings in dolomites in the Death Valley region "believed to be algal." Deposits of algal limestone in Los Angeles County have been described in more detail by H. W. Hoots. A few papers by R. N. Nelson and H. G. Schenck (28, 29) have been noted. N. L. Taliaferro (33) has mentioned "Two types of algal rocks . . . but both are calcareous. Calcareous spring deposits, formed largely by algae, are numerous as transgressive vein-like bodies in the lower part of the middle Miocene and occasionally there are bedded algal limestones. The nature of these is perfectly apparent as the organic structures have been, as a rule, little modified by recrystallization."

Calcareous algae have been recognized in other parts of the world over almost the entire range of geologic time from the Proterozoic to the Recent. They also exist at present over a wide temperature range from tropic waters to the far north. Not all algae are "seaweeds" as they occur in brackish waters as in the Great Basin, in fresh water and in hot springs such as those in Yellowstone Park, where they have formed interesting calcareous deposits. J. Harlan Johnson (43) has written an interesting paper, *Geologic Importance of Calcareous Algae, with Annotated Bibliography* in which there are excellent illustrations of many types of algae.

USES OF LIME AND LIMESTONE

The uses of limestone and of lime, and lime hydrate made from it, fall under three major heads—agricultural, construction, and chemical industries. In addition, these products have a multitude of miscellaneous uses of every-day importance. It is likely that limestone affects human existence in more ways (many not commonly known) than any other mineral except water and common salt.

It has been estimated that about 15 percent of the United States is underlain by limestone, but because it is usually so cheap, little limestone is mined underground. The opening of such a mine may be due to some local condition such as the exhaustion of surface supplies near an established plant, or the need for stone of a particular quality. Cost of transportation is an important factor in the case of a cheap product and this restricts the distance it can be profitably shipped. Improvements in trucks, cheap Diesel-engine fuel, increased loads and speeds, and better roads have resulted in reducing ton-mile costs to the point where limestone in some cases has been hauled as much as 25 miles by truck, and lime from San Bernardino County is said to have been moved recently into the San Francisco market, a distance of over 400 miles by rail. A substantial tonnage of limestone and dolomite from southwestern Nevada goes into the Los Angeles area, a distance of nearly 300 miles, and marl from near Pyramid Lake in Nevada moves into north-central California. A producer of high-grade lime in Missouri has shipped carload lots into California. All of this business could and should be supplied from California properties.

From the above it can be seen that no high-grade limestone deposit should be excluded from consideration if within reasonable distance of a railroad, in a state where manufacturing is increasing so fast.

The largest consumers of limestone in the state are the portland cement plants which made 14,599,752 barrels, or 16 percent of all such

cement made in the United States in 1944. Their consumption of limestone, oyster shells, and travertine has probably been between $2\frac{1}{2}$ million tons and 5 million tons per year in the past decade, although no statistics have been published by the state to show the tonnage of raw materials used in cement.

Other important uses in this state have been in agriculture, including use in processed feeds for poultry and stock, and as fillers in commercial fertilizers; in beet sugar making; for smelter flux, chiefly for iron and steel; and for making lime. Much of the lime used by sugar refiners goes back to the beet growers in the form of a low-grade calcium carbonate for use on their land, without coming on the open market. In the San Francisco area especially limestone is also used for macadam and concrete aggregate. The total reported for 'industrial' uses excluding aggregate in 1944 was 734,425 tons which included 164,494 tons used for lime, 102,220 tons used for all agricultural purposes, and 216,970 tons of fluxing stone. Sugar making requires 150,000 tons or more a year. The balance is used in a great many other industries, some of which are important consumers of limestone in other parts of the country, but are not yet sufficiently represented in California to consume much raw material. Among these are glass plants, paper mills, and chemical industries. The amount of limestone used for macadam and concrete aggregate, not included in the above, was 476,510 tons in 1944, according to the U. S. Bureau of Mines.

The output of dolomite increased in California during the war on account of its use in producing magnesium, and due to the expansion of the steel industry. Most of the dolomite was burnt to lime, but some was used as carbonate for furnace flux and refractories, and for miscellaneous purposes where it was acceptable in place of high-calcium limestone. The commercial term "dolomite" has a rather loose application, and some of the stone so described would be more accurately called magnesian limestone. Dolomite production in this state reached an all-time high in 1943 of 331,251 tons, dropping to 217,018 in 1944, the latter being 10 times the output for 1941.

The following notes on the uses of lime, limestone and dolomite are not complete, but are intended to give an idea of the principal applications, and of some of the minor uses that may be little known.

Agricultural Uses

Although California is one of the leading agricultural states, the use of lime and limestone on the land has not reached the importance it has in other states. This is due partly to the short time during which much of our land has been farmed, and partly to moderate or light rainfall, and drainage conditions, which have resulted in retention of calcium in the soil. Much of the limestone (161,752 tons in 1943 and 102,220 tons in 1944) reported as used for agricultural purposes in California was used as filler in commercial fertilizers. Such products are analyzed, rated and sold primarily for their other constituents. Conversely, most of the lime used in the beet-sugar refining goes back to the beet growers for use on their land and little of it finds its way to the open market. When it is so marketed, it is represented to contain from 60 to 70 percent $CaCO_3$.

Other farm uses are for stock feed and poultry grit, and in various liquid sprays used on fruit trees, and in dry powder insecticides.

The total tonnages of lime, limestone, shells, marl and hydrated lime used directly as "agricultural minerals" according to the report of the State Department of Agriculture in 1944 in California were as follows:

	Short tons
By-product lime	21,498
Hydrated lime	4,576
Limestone, shells, and marl	3,338
Total	29,412

This is only the material sold in the open market for its calcium content alone, under license by the Department of Agriculture, and does not include the much larger tonnage of beet-sugar lime already mentioned, nor the tonnage used in commercial fertilizers, and in processed feeds for poultry and stock.

Need for Calcium in Agriculture

Where there is ample rainfall and good drainage, limestone or lime ultimately must be added to soils used for many crops. Nearly 2000 years ago, Pliny wrote as follows on this subject: "The peoples of Britain and Gaul have discovered another method for nourishing the land. There is something they call marl (marga). It contains a more condensed richness, a sort of fatness of the land." Cato in 200 B.C. also mentioned the use of lime and marl on land.

The following extracts are from Circular 111, University of California, Agricultural Experiment Station, College of Agriculture, by Chas. B. Lipman:

"1. Lime materials have the power of shrinking clay (deflocculation) and making it more pervious to water and air, by making a large number of crumbs from large, sticky masses. Therefore, it makes clays and clay adobe soils looser, prevents their packing, baking and cracking, makes plowing and cultivating easier, and, in general, makes the soil physically a healthier medium for plant growth.

"2. Lime materials serve as a source of the element calcium to plants. Calcium is one of the 10 essential chemical elements in plant growth.

"3. Lime materials make 'sour' soils 'sweet.' Speaking correctly they change an acid soil condition to a slightly alkaline one. Acidity of soils is very detrimental to the growth of many agricultural crops. A slightly alkaline condition is ideal for them.

"4. Lime materials are necessary for useful and beneficial bacteria and other microorganisms of the soil. It furnishes these the element calcium, which is as essential to them as to the higher plants. It promotes a slightly alkaline condition which is ideal for their development. By its physical effects, lime produces good air and moisture conditions for bacteria as above described.

"5. Lime materials promote the normal decay of soil organic matter through their effects on the agencies of decay above described. The normal decay of organic matter in soil prevents accumulation of poisonous materials in soils which are detrimental to plant growth.

"6. Lime will not neutralize sodium carbonate or black alkali.

Lime on Heavy Soil.

"From 1 to 2 tons of burnt lime or hydrate or from 2 to 4 tons of ground limestone (per acre) may be safely applied to improve the working qualities of heavy soils. It may be applied by a spreader or spread with a shovel and should be well plowed in at a time when there is sufficient moisture in the soil for the lime to act well.

"Burnt lime or hydrated lime is to be preferred to the carbonate of lime for making heavy soils lighter, if the cost will allow. The first two forms act more vigorously and more quickly. Applications of lime are best made prior to fall or winter plowing or several months prior to planting. This must particularly be borne in mind if either burnt lime or hydrated lime are employed.

Lime on "Sour" or Acid Soils.

"If 'sour' soils are also heavy clays or clay adobes, the recommendations for the use of lime above made for heavy soils are to be followed. If sour soils are loams, silts or sands the ground limestone is to be preferred to the other forms of lime where it is obtainable. Test the soil with litmus paper. If soil proves neutral, small applications, not over one ton ground limestone per acre, should be made."

In California where dairying is an important industry, and much alfalfa is grown, the following statement by L. F. Graber and others in a bulletin of the Wisconsin Experiment Station is of interest:

"The average acre yield of alfalfa needs more than 8 times as much lime for its growth as do timothy, oats and rye. It is easy to throw away time, labor, seed and money by trying to grow alfalfa on sour and lime-deficient land without the use of some suitable form of lime.

"Alfalfa is a lime-hungry plant, requiring nearly 100 pounds of lime, which the roots must extract from the soil, to make a ton of cured hay. Lack of lime in the soil has caused thousands of failures with alfalfa."

Relative Values of Different Forms of Lime

Commercially hydrated lime is the most quickly available form in which lime can be added to soil and should be added when preparing the seed bed for alfalfa. If limestone is used, it should be finely ground. The Ohio Experiment Station has the following to say in regard to the relative merits of limestone (the natural ground stone, $CaCO_3$) and lime (CaO):

"In actual practice, the experiments made by the Ohio Experiment Station have shown no practical superiority of one form of lime over the other, provided the limestone has been so ground that 80% of it will pass through a sieve having 100 meshes to the linear inch, and provided, of course, that the two materials have been used on the basis of the actual calcium contained."

In figuring the relative value of the different forms, it should be remembered that 100 pounds of pure limestone ($CaCO_3$) contains the same weight of calcium as 56 pounds of quicklime (CaO) or 74 pounds of lime hydrate ($Ca(OH)_2$). The faster action of the hydrate is due to the fact that in the process of slaking it breaks down into a very fine powder.

The final decision on what form shall be used will depend on the availability and relative costs of delivering a certain weight of calcium. There are few lime kilns in California, but limestone deposits are widely distributed. The cost of mining and grinding limestone can be kept low, as most of our deposits can be worked in open quarries, and limestone can be cheaply crushed. The agricultural limestone business is important in most of the leading farm states east of the Rocky Mountains. In 1944 Illinois produced 4,112,350 tons valued at $1.04 a ton; Ohio produced 2,122,090 tons, and Indiana, Iowa, Missouri, Pennsylvania, Tennessee, Virginia and Wisconsin producers sold or used from 1,000,000 to over 1,500,000 tons in each of those states (Bowles, O. 46, pp. 1263-1264). The total reported for the United States in 1944 was 18,941,220 short tons with an average value of $1.34 a ton.

Much of this limestone is a by-product from preparation of stone for other uses. As the industrial uses of limestone increase in California there will be additional amounts of such dust and fines available.

Quicklime used here for soil treatment is also usually of a lower grade than the ordinary commercial product. A few analyses of calcareous products used as "agricultural minerals" in California follow. These were made by the State Department of Agriculture.

Analyses of lime, limestone, hydrated lime, and marl

Registrant	Product	County	Date	Percent $CaCO_3$	Percent $Ca(OH)_2$	Percent passing 40-mesh sieve	Percent passing 100-mesh sieve
California Portland Cement Company	Hydrated lime	Colton, San Bernardin County	1943	23.23	74.98	99.00	83.00
Chubbuck Lime Company	Hydrated lime	Chubbuck, San Bernardino County	1943	14.83	79.92	-------	-------
Collins and Green	Beet sugar lime	-------	1943	65.10	-------	98.00	95.00
Growers Fertilizer Company	Beet sugar lime	-------	1944	66.10	-------	-------	-------
Henry Cowell Lime and Cement Company	No. 2 commercial lime	Santa Cruz County	1943	-------	79.92	40.00	46.20
Vita Growth Products Company	Calcareous marl	-------	1943	57.48	-------	-------	-------
Vita Growth Products Company	Calcareous marl	-------	1944	49.51	-------	-------	-------
Pacific Portland Cement Company	Agricultural lime from ground oyster shells	San Mateo County	1943	94.78	-------	93.00	66.00
U.S. Lime Products Company	Agricultural hydrated lime	Sonora, Tuolumne County	1943	-------	88.06	99.00	87.00
Western Lime Products Company	Oyster shell meal	Santa Susana, Ventura County	1943	91.59	-------	56.00	16.00
			1944	91.87	-------	-------	-------
Diamond Springs Lime Company	Hydrated lime	Diamond Springs, El Dorado County	1942	-------	85.84	99.40	85.70

Besides the calcareous products originating in California and used for agricultural purposes which are accounted for in state statistics, a substantial tonnage of marl enters the state from Nevada and is used as a soil conditioner and as a component of processed feeds for poultry and livestock. As a soil conditioner it is reported to have been sold in the Salinas, Napa, Sonoma, Winters and Sacramento districts. The producers of this marl have been able to gain this market because their price of $12 a ton includes the service of spreading the material on the land. The marl is represented to carry 60 percent $CaCO_3$.

Metallurgical Uses

Fluxing

Fluxing stone used in smelting and refining metallic ores is consumed mostly in the iron and steel industry. In 1944, about 27 percent of the crude crushed limestone marketed in the country was employed for this purpose, the total so used being over 31,000,000 short tons (Bowles, O. 46, p. 1266). In California, 216,970 short tons of limestone was used for fluxing (Bowles, O. 46, p. 1263). Lime also is used, and in 1944 a total of 35,132 tons was consumed in this state in metallurgy. In addition to its use for fluxing, there is in normal times a small tonnage of lime used in cyanide and flotation plants employed in gold recovery.

Limestone is used in iron blast furnaces to form with silica and alumina a slag which is fluid enough to flow freely and to permit complete separation of the iron. The lime and magnesia form double silicates with the silica and alumina in the ore and fuel, and also remove sulfur. While there do not appear to be exact specifications for fluxing stone it should be as free as possible from alumina, silica, sulfur, phosphorous or any other material which will either use up part of the lime by chemical combination with it, or which will lower the quality of the iron.

Physical character of the stone is important as it must be strong enough to help support the weight of the charge in the furnace shaft. In general, this calls for a firm-textured, fine-grained high-calcium limestone such as would make good lump lime. The sulfur content should not exceed 0.5 percent and phosphorus should not exceed 0.01 percent for Bessemer iron nor 0.1 percent for non-Bessemer iron. There is prejudice against magnesian limestones, although there seems to be a lack of definite data to support this. Bowles (29), whose paper *Metallurgical Limestone* is one of the few on the subject, concluded that lime and magnesia are about equally effective in removing silica and alumina, and that slags are so complex that it would be difficult to decide what effect one constituent, such as magnesia, might have on their viscosity. Many blast furnace operators use magnesian limestone, and many considerations such as relative availability, cost, freedom from silica and alumina, and possible use of the slag, may influence the choice.

Either lime or limestone may be used; and here again several factors may help to decide which would be best. Limestone is cheaper and easier to handle, takes a lower freight rate, may be shipped in bulk in open cars and suffers no damage from weather if stored in open stockpiles. It is dried and heated in the upper zone of the furnace by heat that would be otherwise wasted, and this heat, as well as that required for calcination, costs less at the blast furnace than at a lime kiln. The advantage of using lime would be principally an increase in furnace capacity.

It is desirable, if possible, to have the limestone used in blast furnaces about the same size as the ore and coke, but in some cases the ore makes a good deal of fines. Fluxing limestone is sold in sizes ranging from under 1 inch to 6 inches and the size may be specified by contract. One company preparing its own stone uses sizes between 1 inch and 4 inches, and disposes of fines for other purposes. Some work has been done in sintering fine iron ore before smelting, and also in sizing the ore and feeding different sizes separately, in order to give more uniform flow of the ascending gas which reduces the ore.

A blast furnace producing pig iron from ore containing 51 percent iron would require about 1 ton of limestone for every 4 tons of iron ore, more or less, depending on the nature of the gangue minerals. The blast furnace at the Fontana plant of Kaiser Company, Incorporated, in San Bernardino County, is the largest consumer of fluxing limestone in California. Its reported capacity is 2500 tons of ore, or 1200 tons of pig iron daily. This plant also has six open-hearth furnaces using dolomite.

In northern California where steel is made by the basic open-hearth process from pig iron, steel and iron scrap, and small quantities of iron ore, the use of lime made from high-calcium limestone increased during the war. Magnesian limestone and dolomite have also been used as refractories in such furnaces. These furnaces have been using about one-third of the lime produced in California, and the limestone used for making this lime was very high grade, much of it carrying about 98 percent $CaCO_3$ and only small amounts of silica, alumina, etc. A 100-ton open-hearth furnace charge would be about as follows:

55 to 60 tons steel scrap
55 to 60 tons pig iron
8 to 10 tons limestone (or lime)
5 to 6 tons iron ore

Until the manufacture of magnesium from dolomite started during the war, most of the dolomite produced in the state was used as a refractory and as a flux in open-hearth steel furnaces. The tremendous increase during the war came mostly from Monterey County, and was only partly attributable to expansion of the steel industry.

Limestone is used in smelting ores of antimony, copper, and lead. Of these, there is at present only one lead smelter in the state. Formerly, several copper smelters were in operation in California and used limestone for flux. None has been active for about 22 years.

From 1907 to 1914, high-grade charcoal pig-iron was made by electric smelting at Heroult, Shasta County, using iron ore and limestone mined near the plant. During World War I, the manufacture of ferro-manganese and ferro-silicon was started and was carried on in place of iron smelting. The furnace charge for making ferro-manganese was about as follows:

2000 lb. manganese ore (40% Mn, 16% SiO_2, 1-3% Fe)
800 lb. limestone
60 lb. fluorspar
70 lb. iron ore (68% Fe, 1-2% SiO_2)
550 lb. charcoal or coke (crushed fine)

This plant was closed about 1919. The process was technically successful, but operating costs and freight rates were high. In particular, electricity would have to be available at a fraction of its former cost, and a more dependable supply of coke would be needed to permit successful operation.

Lime in Gold-Recovery Processes

Lime is used in the cyanide process to neutralize acidity caused by oxidation of sulfides in the ore or concentrate being treated for recovery of gold and silver. It is generally used in small quantity, as it is desirable to have the solution only mildly alkaline. It may be used as quicklime, either ground or granulated, or may be slaked or made into milk of lime before introduction. For this use, a high-calcium lime free from carbon and low in magnesia is required.

In the flotation process, a similar quality of lime is used to render solutions slightly alkaline.

Lime is also useful in settling slimes produced in milling some ores. Under the state law, placer mining operators are in some cases required to mix aluminum sulfate and lime, or an equivalent clarifying substance to the effluent from their mining operations before it enters streams tributary to Sacramento and San Joaquin Rivers, to coagulate and cause the settling of solid materials.

Uses in Building

Limestone

In California no limestone except marble and terrazzo is used directly for building. There are numerous large deposits of excellent marble in the state. Marble production began in the sixties and was carried on until 1942, when it may be said, for practical purposes, to have been suspended with the closing of the Columbia marble quarry in Tuolumne County, although there has been a very small output of crushed stone for terrazzo, and a little onyx and serpentine have been sold. California marbles have been widely used locally for interior work with excellent satisfaction. Marble has shared the same fate as sandstone and granite, both of which were once produced here in substantial quantities. These natural building stones, which require skilled labor at good wages, especially for cutting to finished size and polishing, have not been able to compete with cheaper products made and erected with a minimum of unskilled labor. In addition, marble must compete with that brought from other states or from outside the country.

Crushed Limestone

In many parts of the United States crushed limestone is widely used as aggregate in concrete, and in some cases plants have even been erected to make sand from limestone. Except for a few cases, concrete aggregate in California is supplied by silicate rocks of the ''trap'' and ''granite'' types, either quarried from deposits in place or dug as boulders and gravel from stream beds, often in the course of gold dredging. Sands used here are the natural stream deposits, composed almost entirely of quartz.

Lime

Quicklime and hydrated lime for use in mortar, plaster, stucco, and masonry cement may be made either from high-calcium or high-magnesium limestone. The following are the standard specifications for quicklime for structural purposes, as issued by American Society for Testing Materials, C5-26:

	Calcium lime	*Magnesium lime*
Calcium oxide, minimum	75%	--
Magnesium oxide, minimum	--	20%
Ca and Mg oxides, minimum	95%	95%
SiO_2, Al_2O_3, iron oxides, maximum	5%	5%

Maximum CO_2 allowed is 3 percent if sampled at kiln; or 10 percent elsewhere.

Standard specifications, American Society for Testing Materials, C6-31: for hydrated lime, calcium and magnesium oxides together must be not less than 95 percent of the non-volatile portion, CO_2 not over 5 percent if taken at the place of manufacture or not over 7 percent if taken elsewhere. The residue on a 30-mesh sieve must not exceed 0.5 percent and on a 200-mesh sieve must not exceed 15 percent. The plasticity figure must be not less than 200 when tested with the Emley Plasticimeter.

High-calcium lime is favored by many because it slakes more rapidly and makes a greater bulk of hydrate than high-magnesium lime. Care is needed with the latter to be sure it is thoroughly slaked, but if this is done it is said to yield a superior mortar. The preparation of hydrate in commercial plants under proper controls is now common practice. Lime hydrate mixed with water to the proper consistency is prepared and aged under the Brooks patents issued in 1931, and is sold in several cities where large numbers of brick buildings are erected. It is comonly known as ''lime putty.'' In such places it is also made up with sand into mortar and this is at times handled in transit mixers for delivery to the job in the same manner as ready-mixed concrete.

Portland Cement*

Portland cement consumes more limestone than all other uses in California. All of it so used is ''captive'' tonnage, and no state statistics have been published giving the tonnage or value. However, the record of cement production may be used to arrive at an approximate annual figure for limestone used for cement. In 1943 the total portland cement production in California was 18,515,085 barrels of 376 pounds each or 3,480,279 short tons. If it is assumed that the average lime content of all portland cement made in the state is 65 percent, and that all limestone so used will average 90 percent $CaCO_3$, the total consumption of limestone for this purpose was about 4,488,000 short tons. Of course there are several varieties of cement made in which the analysis may vary from that of general-use, moderate heat cement, but it is believed this estimate is not more than 10 percent in error.

As to a value that might be assigned to this limestone, this is a matter of bookkeeping. A variety of methods in mining or dredging the limestone of course leads to probably wide differences in raw material costs. The actual cost of producing crude limestone will vary from a few cents a ton for oyster shells to a maximum of possibly 80 cents a ton if present high wages in other industries ($10 to $11.50 a shift) have to be met. Incidentally, in the U. S. Census figures of California manufacturers for 1939, when 10,984,033 barrels of cement was made in California the total cost of ''material and supplies'' for the 10 cement plants then in operation was reported as $3,685,143.

It is possible to use a rather wide variety of raw materials in making portland cement, if the mixture gives certain proportions of desired ingredients and does not exceed the limits set for some not wanted. Thus, in the Lehigh district, Pennsylvania, extensive use of an

* This section on *Portland Cement* and flow-sheet of the cement plant (fig. 1) were supplied by Permanente Cement Company.

argillaceous limestone is made, requiring addition of little clay, and small amounts of high grade limestone. In California, cement companies in the past have generally used high-calcium limestones and no beneficiation of low grade material was attempted previous to the advent of Permanente Cement Company.

A mild climate, cheap oil or natural gas fuel and plenty of high grade limestone have been basic advantages here. In 1940, California with about $\frac{1}{20}$ of the country's population, produced over $\frac{1}{10}$ of all portland cement made in the United States. In 1945, the last year for which details are available, five cement plants in northern California shipped 7,446,421 barrels and six plants in southern California shipped 8,417,713 barrels, a total of 15,864,134 barrels of cement, valued at $23,469,662. In 1946, the estimated total state production was 21,200,000 barrels of an estimated total value of $33,708,000. The total capacity of California cement plants was 27,740,000 barrels as of January 1, 1946. As noted herein, several of the plants have increased or are at present increasing their capacities. About 2300 men are employed in the state's cement mills.

Minor Structural Uses of Lime

As an Additive in Concrete. The addition of a small quantity of lime hydrate to concrete is said to make it much easier to work and cuts down water absorption. The waterproofing effect is due partly to the very small size and colloidal nature of the lime particles and to the natural viscosity of the lime hydrate. It is believed that it seals the voids existing particularly in lean concrete mixes. The National Lime Association has issued an interesting pamphlet giving results of tests with lime hydrate in concrete. They suggest the use of 12 pounds of lime hydrate to each sack of cement (94 lb.) in a $1:2\frac{1}{2}:5$ mix. The Life Sciences Building on the Berkeley campus of the University of California was built of concrete with added lime hydrate.

Sand-Lime Brick. These are made of fine-grained clean silica sand mixed with hydrated lime in the usual proportion of 92 percent sand and 8 percent lime. The sand and lime are thoroughly mixed, moulded in a brick press and cured for 8 hours under 120° steam pressure. The lime hydrate must be made from high-calcium lime containing less than 5 percent MgO and the sand should contain about 15 percent of minus 100-mesh.

Silica Brick. Quartz or quartzite ground to minus $\frac{1}{4}$ inch is mixed with 2 to 3 percent slaked lime, and the mixture is ground for 15 to 30 minutes and made into bricks. These are dried and burned at a maximum heat of cone 12 to cone 18. These bricks are widely used for lining open-hearth steel furnaces, coke ovens, glass-melting furnaces, and other types of furnaces and fire boxes subjected to high temperatures.

The lime should contain not less than 93 percent CaO, not over 4 percent MgO, and not over 1.5 percent aluminum and iron oxides. The quartz or gannister should carry 97 percent or more silica and not over 0.4 percent alkalies.

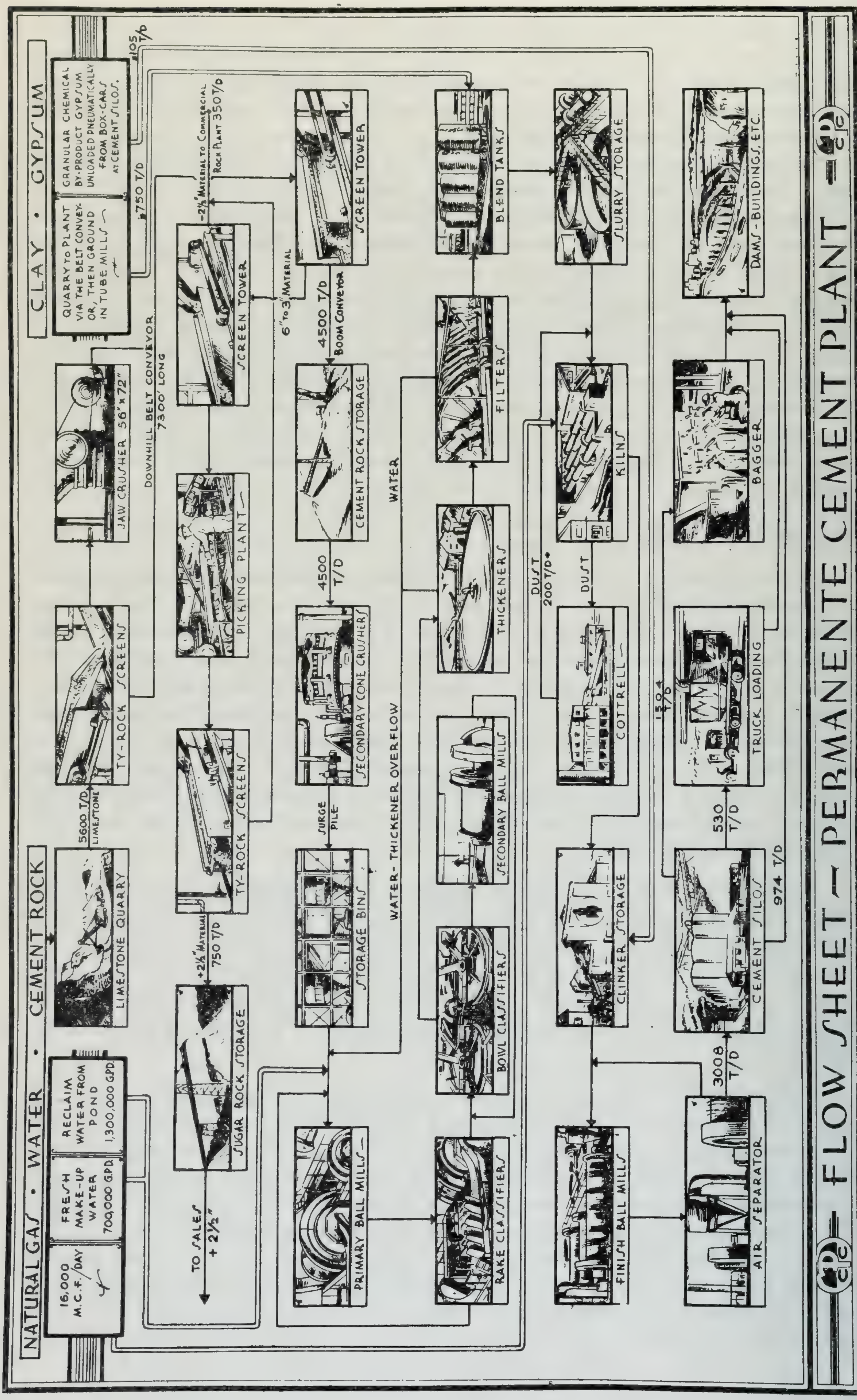

NATURAL GAS • WATER • CEMENT ROCK • CLAY • GYPSUM
16,000 M.C.F./DAY
FRESH MAKE-UP WATER 700,000 G.P.D.
RECLAIM WATER FROM POND 1,300,000 G.P.D.
QUARRY TO PLANT VIA THE BELT CONVEY-OR, THEN GROUND IN TUBE MILLS
GRANULAR CHEMICAL BY-PRODUCT GYPSUM UNLOADED PNEUMATICALLY FROM BOX-CARS AT CEMENT SILOS.
750 T/D
105 T/D
LIMESTONE QUARRY
5600 T/D LIMESTONE
TY-ROCK SCREENS
JAW CRUSHER 56"x72"
DOWNHILL BELT CONVEYOR 7300' LONG
SUGAR ROCK STORAGE
TO SALES +2½"
+2½" MATERIAL 750 T/D
TY-ROCK SCREENS
PICKING PLANT
SCREEN TOWER
-2½" MATERIAL TO COMMERCIAL ROCK PLANT 350 T/D
6" TO 3" MATERIAL
SCREEN TOWER
4500 T/D BOOM CONVEYOR
CEMENT ROCK STORAGE
4500 T/D
SECONDARY CONE CRUSHERS
SURGE PILE
STORAGE BINS
PRIMARY BALL MILLS
WATER
WATER-THICKENER OVERFLOW
RAKE CLASSIFIERS
BOWL CLASSIFIERS
SECONDARY BALL MILLS
THICKENERS
FILTERS
BLEND TANKS
SLURRY STORAGE
KILNS
DUST
DUST 200 T/D
COTTRELL
CLINKER STORAGE
FINISH BALL MILLS
AIR SEPARATOR
3008 T/D
CEMENT SILOS
530 T/D
974 T/D
TRUCK LOADING
1504 T/D
BAGGER
DAMS-BUILDINGS, ETC.
FLOW SHEET — PERMANENTE CEMENT PLANT

FIGURE 1

Insulation. Limestone and dolomite, of grades possibly unsuitable for other uses, might in some cases have value for making rock wool if situated near cheap fuel and transportation and in a deposit that could be cheaply mined. The price obtainable for such crude rock is usually low as it has to meet competition from other cheap natural material and from slag and glass.

Such a rock might be used alone if it contained the right proportions of the carbonates and of silica; or in combination with clay, shale, or chert. The rock or mixture of rocks should carry 50 to 65 percent of either $CaCO_3$ or $MgCO_3$ (or any combination of the two) and the balance should be chiefly silica and alumina.

Calcium Carbide and Calcium Cyanamide

Calcium carbide, and calcium cyanamide made from it, require cheap and abundant high-calcium limestone, coke or anthracite, and cheap electric power. California lacks the high-quality coke, but now has low-cost hydroelectric power available from Shasta and Boulder Dams. The limestone must be free from phosphorus and arsenic to avoid danger of forming poisonous phosphine and of exploding acetylene gas, and should not contain over 1 percent MgO, as this increases consumption of electric current. Alumina should also be low. Other common impurities such as Fe_2O_3 and SiO_2, while not desirable, are apparently not so deleterious as the above.

The lime in this case acts as an oxidizing agent: $CaO + 3C + \text{heat} \longrightarrow CaC_2 + CO$. The lime and coke are pulverized, mixed, and heated in electric arc furnaces to fusion, forming liquid CaC_2, which is cooled to solid form and crushed. The making of calcium cyanamide involves the fine grinding of the carbide, the liquefaction of air with the separation of nitrogen, and the heating of the carbide in the presence of nitrogen to a temperature of 1800° F., when the two combine. Lime has a minor use in this process in removing CO_2 during the liquefaction of air and also as a catalyst. Acetylene gas made from calcium carbide is used in making some kinds of synthetic rubber (including neoprene), has many uses in organic chemistry, and is widely utilized in welding torches.

Calcium cyanamide is used for fertilizer, and as a basis for making other nitrogen compounds. When fused with common salt, carbon, and a small amount of calcium carbide, it yields sodium cyanide, which is widely used in the recovery of gold and silver, and calcium chloride.

Carbon-Dioxide Gas and Dry Ice

There is a very large waste of CO_2 gas from cement kilns, and the only utilization of such gas from lime kilns in this state is in the case of beet-sugar refiners who burn their own lime and use carbon-dioxide gas for precipitating the lime as calcium carbonate. The general needs of the state for carbon dioxide are supplied from wells in Imperial County near Salton Sea (Rook and Williams 42) and in smaller amounts from wells in Mendocino and Sonoma Counties (Hubbard, H. G. 43). Carbon dioxide is marketed as liquid and solid or "dry ice." The gas from Imperial County is said to be nearly pure, and that from Sonoma and Mendocino Counties shows from 84.5 to 97 percent CO_2, as so far reported.

Carbon dioxide has numerous uses both in war and in peace. Refrigeration will probably offer the most important market. Other important

uses are for fire prevention, carbonating beverages, making of carbonates, and to obtain very low temperatures, in certain chemical operations. It can be safely used as an explosive, and has minor uses for power, and to assist in preserving foods and coffee from spoilage by oxidation.

The price of "dry ice" at retail seems to be rather high, and the amount of CO_2 so marketed is small when compared with that going to waste from lime and cement kilns. As in the case of many minerals which are too expensive to be widely used, it might be found that demand would greatly increase if the market price could be brought to a point where CO_2 could be a competitive product for such uses as the refrigeration of the thousands of carloads of fruit and vegetables which are annually shipped from California. Many changes in refrigeration practice, and probably much equipment for separation and purification of kiln gases would be required.

In the desert regions of California where saline deposits are worked, carbon-dioxide gas produced from dolomite and limestone is used for carbonation in the production of sodium carbonate. This product is made at Owens Lake, Inyo County, and Searles Lake, San Bernardino County. No definite record of the amount of dolomite or limestone used for this purpose is available, as it is partly if not entirely "captive" tonnage. The production of soda ash (Na_2CO_3), however, is large. Another method is known as the Solvay or ammonia-soda process. About 1¼ tons of lime or dolomite is required for each ton of soda ash produced by this method. Part of the soda ash produced at Searles Lake is obtained by crystallization.

Fillers

Perhaps the best definition of a mineral filler is that given in *Industrial Minerals and Rocks* (Emery, A. H. 37, p. 483) as follows: "Finely ground material of mineral origin, used for other than pigment purposes in compounding various products, and which, although sometimes actively changing the properties of the product, are themselves unchanged."

Ground limestone is used as a filler in asphalt, fertilizers, paint, paper, oilcloth, linoleum, cosmetics, tooth pastes and powders, and many other products. There is in many cases a question as to whether the limestone should be called a filler or an important component, because it often performs functions other than merely increasing the volume of the product.

The test of limestone for fillers is in many cases a physical one, including color, fineness and shape of particles, and hardness, but purity may be important, as in the case of cosmetics or tooth pastes where no abrasive like silica is wanted. As a rule, however, the test is empiric and if a certain source of supply proves satisfactory, it will hold its customers.

Glass Making

Most common glass contains lime, which may enter the process in the form of limestone, lime, or hydrate. Lime and lime hydrate are said to permit better control of composition, require less heat, and allow greater capacity. However, with lime there may be trouble from irritating dust, which is avoided with limestone; the latter can also be stored or stockpiled in the open without danger of slaking, as occurs with lime.

Magnesian limestone or dolomite can be used if total carbonates are high and impurities low, in some varieties such as machine bottle glass and sheet glass; magnesium is said to increase the modulus of rupture for flat forms such as window glass. Lime glass is produced in greater quantity than all others and usually carries from 69 to 72 percent silica, 12.5 to 13.5 percent CaO, and 13 to 15 percent Na_2O (Morey, G. W. 42, p. 781; Shreve, R. N. 45, p. 220). The specifications for raw materials become increasingly strict in going from bottle glass through the various grades to crystal tableware. As some impurities may be present in both the silica and the limestone, the demand will be for the best limestone. Alumina, calcium sulfate, and calcium phosphate are generally undesirable as they tend to produce a "stone" in the glass, and alumina gives an opaline cast. However, according to Shreve (45, p. 221), a glass that is high in alumina and lime is useful for liquor bottles because it is chemically resistant. Iron oxide is usually undesirable because it is a strong coloring agent but this effect can be neutralized within limits by decolorizers. Sulphur and phosphorus in anhydride form should not exceed 1 percent for bottle glass and 0.2 percent for optical glass.

The following analyses of lime glasses quoted by Shreve (45) from various authorities give a good idea of the maximum allowances for alumina and iron oxide in limestone to be used for glass. These constituents would carry over without diminution when the limestone is burned to lime.

Dark bottle glass may carry from 0.50 to 0.65 percent Fe_2O_3 and as much alumina, and a combined total of not less than 89 percent CaO and MgO. For other types of lime glass (or lime-soda glass) the combined carbonates must range from 91 percent up to 99+ percent $CaCO_3$ for optical glass. If quicklime is used, the CO_2 content should not be over 3 percent, and in the hydrate CO_2 should be under 5 percent. In general, either quicklime or limestone shoud be ground to minus 12-mesh or minus 16-mesh, with perhaps as much as 50 percent plus 60-mesh and not over 20 percent minus 120-mesh.

A minor amount of $CaCO_3$, usually in the form of manufactured whiting, is used in ceramics for flux and to give a white color.

Paints and Varnish

Lime hydrate is used in a number of cold-water paints, the simplest and best known being whitewash. Precipitated whiting ($CaCO_3$) is used in inside white paints, and ground limestone and whiting in kalsomine, and casein-base or cold-water paints. According to the National Lime Association lime hydrate serves many useful purposes as a protective agent, pigment, chemical agent, cementing agent, and disinfectant in such paints. It prevents rust on iron and steel and helps preserve wood. It is so white and so finely divided that it makes a good pigment, usually without additional grinding. It reacts chemically with casein, milk curd, etc., used as binders for this type of paint, breaking them up by its solvent action.

In varnish, hydrated lime also has important uses (see Bulletin 210, National Lime Association, 1930). It neutralizes the acid in the resin used, and clarifies and hardens the varnish. A very high-grade, high-calcium lime is required for varnish.

Composition of lime glasses

Type of glass	SiO_2	B_2O_3	Al_2O_3	Fe_2O_3	As_2O_3	CaO	MgO	Na_2O	K_2O	SO_3
Machine cylinder	72.88	----	0.78		----	12.68	0.22	12.69	----	----
Sheet	72.9	----	0.7		----	7.9	2.8	15.00	----	----
Polished plate	72.68	----	0.50	0.07	----	12.95	----	13.17	----	0.44
Machine bottle	74.5	----	0.81	0.09	----	5.5	4.1	15.00	----	----
Electric light bulb	72.4	----	0.8	0.4	----	5.3	3.7	17.4	----	----
Crystal tableware	74.2	0.40	----	----	0.2	4.3	3.2	17.7	----	----
Spectacle (0.9 percent Sb_2O_3)	69.04	0.25	----	----	----	12.07	----	5.95	11.75	----

Paper Making

In the *sulphite process* of paper-making, wood chips are treated with an acid liquor made by combining milk of lime with sulfur dioxide, forming in a series of reactions the bisulfites of calcium and magnesium which remain in solution with excess sulfurous acid. This liquor dissolves everything except the cellulose from the wood. A dolomitic lime is preferred as it is said to give a milder and more satisfactory chemical action and a whiter pulp. In a modification of the process, where the gas from sulfur burners passes over lump limestone in towers, high-calcium limestone is sometimes preferred.

The specifications of the American Society for Testing Materials for quicklime to be used in this process are as follows:

	Calcium lime		*Magnesium lime*	
	Max. %	*Min. %*	*Max. %*	*Min. %*
CaO	----	94.3	----	56.5
MgO	2.6	----	----	40.4
Oxides of Fe, Al, Si	3.1	----	3.1	----

In the *soda process,* the liquor used to treat the wood chips has caustic soda for its active agent. During the process much of this is changed to sodium carbonate. This is treated with lime or lime hydrate (preferably lime) to convert it to caustic soda.

In the sulphate process, sodium sulfate is used and the final ash, carrying the soluble parts of the wood and several sodium compounds, is treated with lime to causticize the latter.

The lime used in the soda and sulfate processes should be low in MgO, quick slaking and quick settling and chemically active but not necessarily as high grade as for the sulfite process, as the minimum active CaO content desired is 85 percent.

Rags used for paper are cooked under steam pressure with quicklime and soda ash. The lime should carry 90 percent CaO.

Precipitated calcium carbonate made from high-grade lime is used as a filler in paper.

Strawboard and *pasteboard* are made from straw which has been cooked under steam pressure with milk of lime made from quicklime or lime hydrate. Both high-calcium and high-magnesium limes or an intermediate product can be used, if the total combined oxides are high, and the hydrate is smooth and fine grained.

Sugar Making

The manufacture of sugar from sugar beets in California consumes a large quantity of high-calcium limestone yearly. As the business requires both lime and carbon-dioxide gas, the beet-sugar producers buy crude limestone which they burn in their own kilns. With shaft kilns, a strong, compact, and fine-grained stone is desired. The specifications as to chemical content are also quite strict. Limestone is generally purchased under contract. The sugar-making season is short, so that a large tonnage of stone has to be made available in a period of a few months. It is shipped in lumps 2 by 4 inches and 4 by 6 inches in size, in open cars.

In the treatment of the raw beet juice, known as defecation, milk of lime is added until mild alkalinity is reached. The juice has been previously heated to 80° or 90° C. and is held at this temperature for 5 or 10

minutes. The lime decomposes albumen and other non-sugar bodies, and neutralizes acids. Carbon-dioxide gas is then introduced, precipitating $CaCO_3$ which carries down various solid impurities with it, and the juice is filtered. These processes for making sugar are too complex to be covered in full. Only the principal uses of lime are indicated here.

In the Steffens process, used in some plants, the refuse molasses, which still contains some sugar, is treated with finely ground quicklime, which forms with the sugar insoluble calcium trisaccharate. This is filtered and added to raw beet juice instead of milk of lime as in the previous process. It performs the same work as the latter.

Lime amounting to about 2 percent of the weight of beets is used in treating beet juice, while with cane juice less is required, although better filtering action is said to be obtained by using nearly as much as for beets. As CO_2 is not required for cane juice, cane sugar producers buy either quicklime or hydrate.

As mentioned before, a very good grade of high-calcium limestone is required for the sugar business. There is no scarcity of such stone in California, but the business of supplying it to the sugar companies has apparently not been attractive enough during the war to the owners of some of the largest deposits in the northern half of the state, so that limestone has been obtained from more remote deposits in San Luis Obispo and Siskiyou Counties. Two new quarries were opened to help fill this demand—one in Amador County, in 1945, and one in El Dorado County in 1946. A limestone that will yield a lime containing a minimum of 90 percent sugar-soluble CaO and a maximum of 3 percent MgO with very little Fe_2O_3, Al_2O_3 and SiO_2 is desired. Many analyses of samples of limestone from deposits in the state are available that show from 96 to 99 percent $CaCO_3$, less than 1 percent $MgCO_3$ and less than 1 percent R_2O_3. These would be suitable for such use. The "sugar limestone" business involves an annual consumption of over 100,000 tons in California.

Treatment of Water and Water-Borne Wastes

Water Treatment. Lime and its hydrate serve several purposes in water. For temporary hardness, caused by the bi-carbonates of calcium and magnesium, lime hydrate causes precipitation as the normal, almost insoluble carbonate, $CaCO_3$, by combining with the CO_2 normally found in water and responsible for holding the calcium in solution. Lime is generally used with aluminum sulfate or soda-ash in treating water for industrial uses, for municipal water supplies, and boiler feed water. Quicklime for such use must contain 90 percent available CaO and lime hydrate 68.1 percent available CaO, under A.S.T.M. Standard Specifications C53-39, 1939.

Sewage Treatment. Lime is one of the chemicals used to coagulate solid material in sewage to facilitate its settling and filtration. Lime also is useful in killing many dangerous organisms in water, and in neutralizing acidity.

Industrial Waste Waters. Waste sulfite liquor from some paper mills yields useful products when treated with lime. Waste pickle liquor from steel and iron plants when treated with lime under a patented process produces material used for building and insulation. Plant wastes from

large chemical and dye factories often require treatment before they can be discharged into streams. Lime or calcium carbonate may be used in such cases to neutralize acidity. If it is available, by-product lime or carbonate may be found suitable, as the requirements would not be strict.

Production of Magnesium

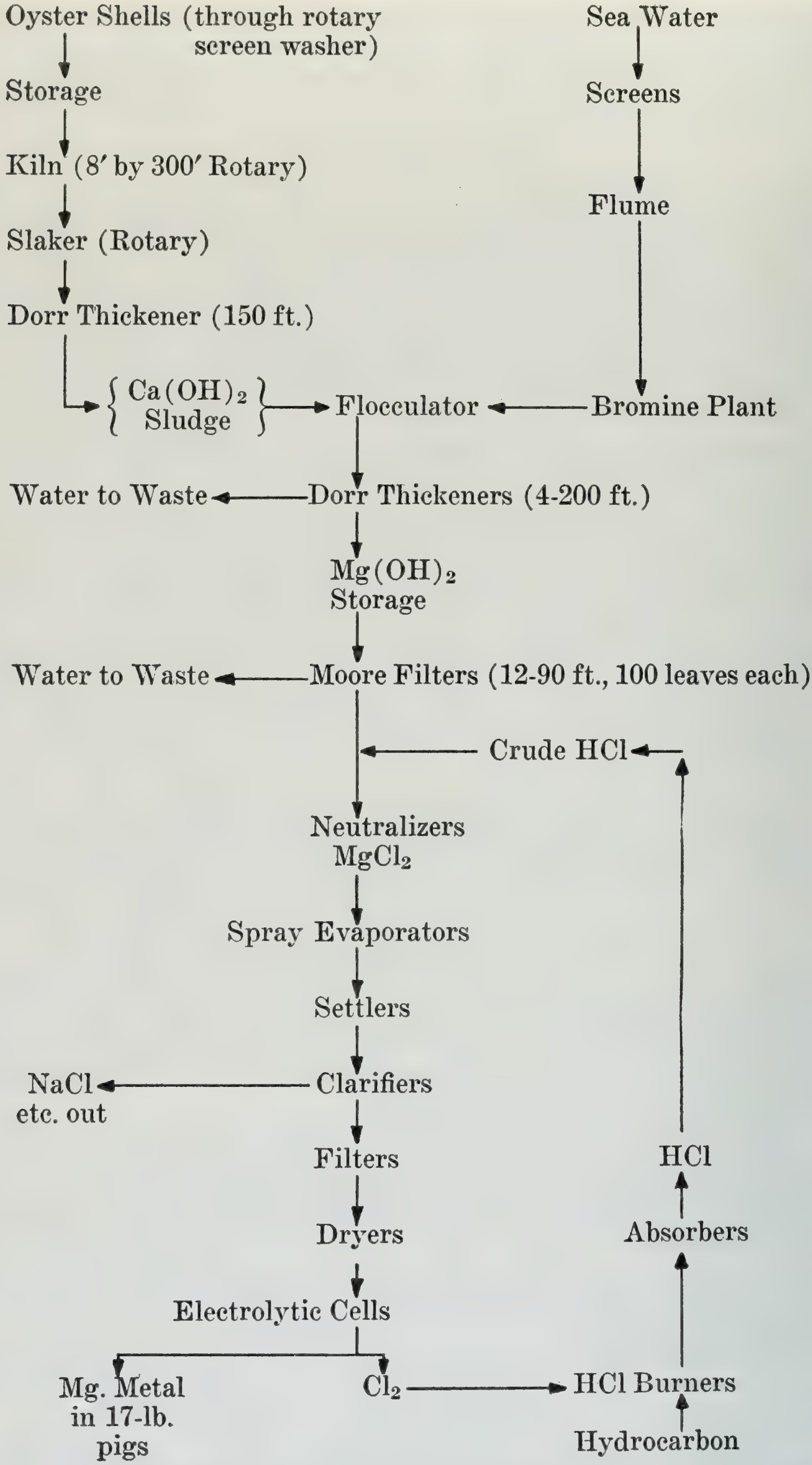
Production from Sea Water. In the great plant of The Dow Chemical Company at Freeport, Texas, where the first commercial magnesium from sea water was produced in January 1941, and where immense quantities of it have since been made more cheaply than by other processes, lime made from oyster shells takes an important part as one of the two raw materials. The shells are dredged from the bottom of Galveston Bay and then taken in barges to Freeport Harbor, where they are washed in a rotary washer and either stockpiled or sent by conveyor to an 8- by 300-foot rotary kiln. After being burnt to lime, this is slaked in a rotary slaker, and is made into a milk of lime in a 150-foot Dorr Thickener. From this it passes to a flocculator, where it mixes with the sea water that has been previously screened, and has been treated for removal of bromine. In the flocculator, the mixing is assisted by agitation. The 1 part of Mg in 770 parts of ocean water is precipitated as $Mg(OH)_2$ by the lime hydrate. This $Mg(OH)_2$ is concentrated in four 200-foot Dorr Thickeners, filtered by twelve 90-foot Moore filters (100 leaves each) and converted to $MgCl_2$ by hydrochloric acid preparatory to electrolytic treatment. The process is described by Kirkpatrick (41) in *Chemical and Metallurgical Engineering,* vol. 48, no. 11, and in *Rock Products,* for January 1942.

Production of Magnesium by Combined Methods in California. In California during the war, dolomite which was mined and calcined near Natividad, Monterey County, was hauled to Moss Landing on the coast where it was treated with sea water. The lime precipitated magnesium from the water and the enriched $Mg(OH)_2$ was then shipped to the Permanente plant in Santa Clara County for making magnesium by the Hansgirg process. In this, the MgO is mixed with petroleum coke and pitch to form briquettes which are then treated in a three-phase, carbon-lined electric arc furnace. The product is a dust carrying about two-thirds metallic magnesium, some MgO, and carbon. This underwent further treatment in electrical retorts.

Pidgeon or Ferro-Silicon Process for Magnesium. This process also uses dolomite as a raw material. The dead-burned dolomite is crushed and made into pellets or briquettes with crushed ferro-silicon. These are heated in sealed metal retorts under vacuum and the product is a high-grade, crystalline magnesium metal. The retorts are made of chrome-alloy and have a condenser tube with a removable lining on which the magnesium collects.

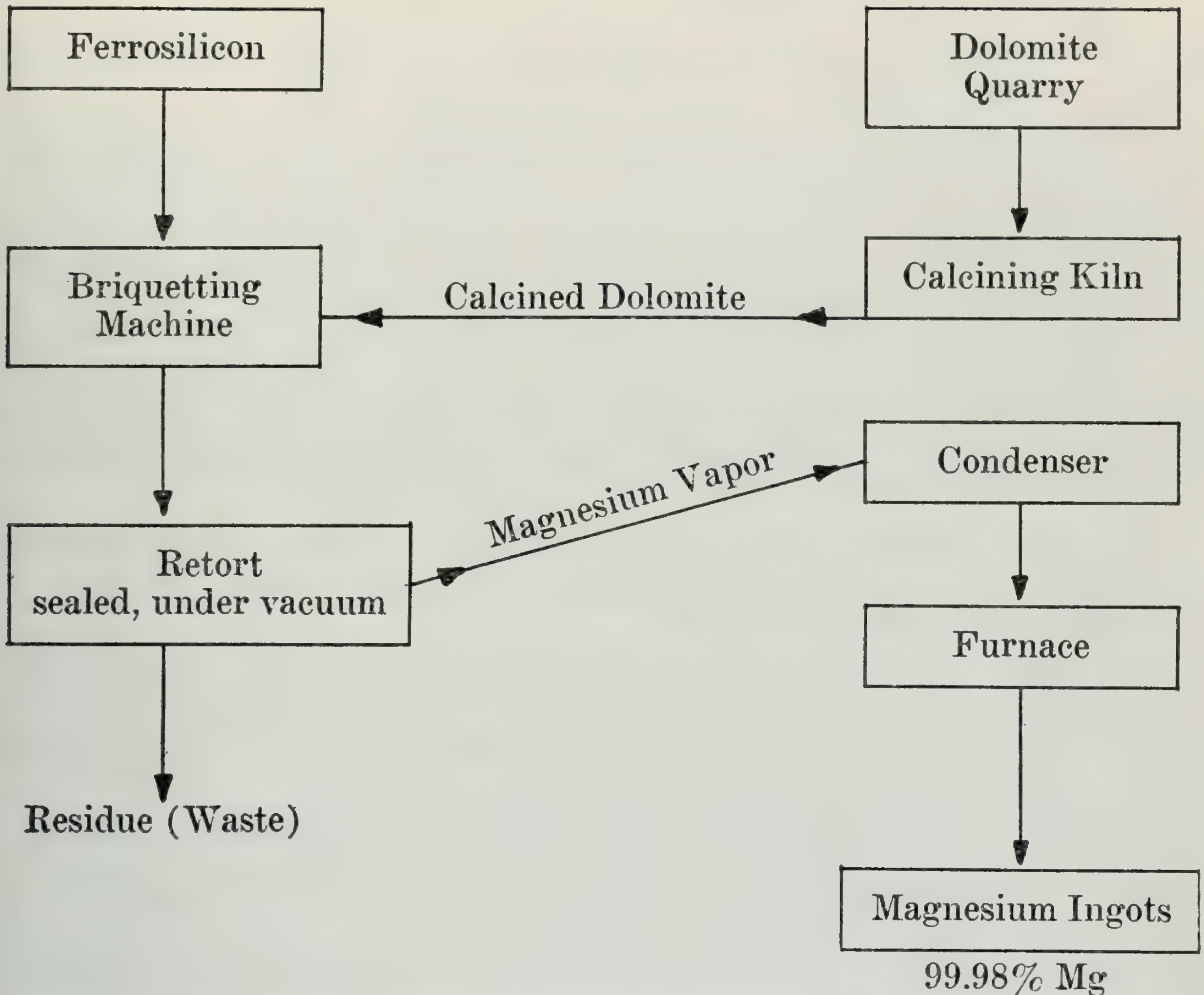
California has ample supplies of the natural raw materials and will ultimately have ample cheap electric power to permit manufacture of magnesium here by any of the above methods at moderate costs.

Production of Magnesia from Salt-Works Bittern Residue. At one plant on San Francisco Bay, lime is obtained from oyster and other shells dredged from the bay, washed on the barge with sea-water, and then



Flow sheet, Dow Chemical Company Magnesium Plant Freeport, Texas, showing part played by lime

(Reproduced from *Rock Products*, Jan. 1942)



Pidgeon Ferrosilicon Process
(Reproduced from *Chemical and Metallurgical Engineering*, vol. 49, no. 4, 1942)

calcined in a rotary kiln. The lime is then used to precipitate the magnesia from salt-works bittern residues.

Other Industrial Uses

Bleaching Powders and Fluid. "Chloride of lime" or "chlorinated lime" is made by passing chlorine gas through hydrated lime powder either in large chambers with extensive floor area, or in revolving cylinders, the latter equipped with blades or screw conveyors to keep the hydrate in motion and increase exposure to the gas. Fluid bleaches are sometimes made by direct action of chlorine gas on milk of lime.

The limestone used to make the lime and lime hydrate for these purposes should contain very little iron oxide, no sulfur, titanium, nor phosphorus, and, as quick slaking is desired, it must be a high-calcium stone carrying 96 percent or more $CaCO_3$.

Butter Making. Small amounts of lime are used to control acidity of cream used in butter-making. Magnesian lime is said to be best for the purpose.

Explosive. Quicklime and carbon dioxide can both be used as explosives where a gentle heaving action is desired to avoid shattering, or where it is necessary to avoid gas explosions.

Gelatine and Glue. Quicklime and lime hydrate made from a high-calcium limestone low in iron oxide is used for treating the hide pieces, connective tissue, bones, etc. used in making these products.

Glycerine, lime soaps, and lubricating greases are produced by the action of lime hydrate with animal or vegetable fats. In the process, glycerine is liberated from the fat. The remaining calcium jelly is mixed with a mineral oil to form cup grease and axle grease. Rosin greases are made from lime hydrate and mineral oil, with rosin added to the mixture. The black, sticky grease used for lubricating wire rope, heavy gears and railroad curves is similarly made with "summer black oil". Lime for such use must be of the high-calcium type, and should not contain over 1 percent MgO and not over $1\frac{1}{2}$ percent of SiO_2, Al_2O_3 and Fe_2O_3, and 98 percent of the hydrate should pass a 250-mesh screen.

Leather making utilizes high-calcium, quick-slaking lime for removing hair from hides; but for morocco leather, made from goat skins, a high-magnesium lime is required.

Mine Dusting. Ground limestone or dolomite is useful for rock-dusting in bituminous coal or lignite mines to help prevent and to limit the spread of explosions and fires of gas and coal dust, and this practice has been urged for many years by the U. S. Bureau of Mines. To be effective, it has been determined in some cases that after rock-dusting, the mine dust mixture should contain at least 65 percent incombustible material; some mines have maintained it from 70 to 88 percent incombustible. For this use, the limestone or dolomite should be high in carbonates and low in silica. It should be ground to minus 60-mesh with 60 percent passing 200-mesh.

Poultry Grits and Animal Foods. Ground or finely crushed limestone, sometimes made from the undersize where limestone of specified coarser sizes is being prepared, is utilized for these purposes. About $1\frac{1}{2}$ pounds of calcium carbonate is said to be necessary in each 100 pounds of basal chick feed to insure against leg weakness and to provide the proper mineral content for the bones. Marl is acceptable for such use, and a large part of that shipped into the state from Nevada is said to be used in such processed feeds, principally poultry feeds, which are made in large quantities in California.

Road Improvement and Stabilization. Although agricultural lands are rarely suitable for all-year roads, probably 80 percent of country roads and private farm roads are on such lands and will be for a long time. Silts, loams and clay become sticky when wet and cling to the feet of men and animals, and to the wheels of vehicles. Furthermore, when such soils are wet they lose their bearing power and ruts and mud-holes are formed.

The results of a test on a section of road in Missouri was reported by Dean McCaustland of the University of Missouri. Treatment of the top layer to a depth of 5 inches with 2 percent dry lime hydrate in one case and 5 percent in another, and to a depth of only 2 inches with 5 percent dry weight of the hydrate on a third section 250 feet long, were said to give good results. The clay and lime mixture was said not to stick to wheels, did not develop ruts, and packed better than untreated clay. Later work on road stabilization with lime in Texas has been described by Lesesne (40) in Bulletin 325 of the National Lime Association.

DESCRIPTIONS OF LIMESTONE DEPOSITS BY COUNTIES

Age and Geographic Distribution of California Deposits

It is of interest to note that in California the principal deposits of dolomite and of magnesian limestone are in the older rocks. In Monterey and San Benito Counties large deposits of dolomite are the oldest rocks, being roof pendants on granitic rocks. In the desert region are numerous dolomite deposits and dolomitic limestones and many of these have been placed among the oldest rocks of the region. The largest of these, not utilized commercially because of remoteness, are the immense accumulations in the Death Valley region, ranging in age from lowermost Cambrian through Ordovician. Some of this is believed to be algal and much of it has evidently been derived from limestone.

Sierra Nevada

In the western Sierra Nevada region from Tehachapi as far north as northern Plumas County, there are few outcrops of rock older than the Carboniferous. While there are numerous limestone deposits in this region that carry small percentages of magnesium, this is generally no higher than might be expected in rocks derived from most of the marine invertebrates. A great many analyses of such organisms found in other parts of the world have been made. In general, the percentages of $MgCO_3$ found by analysis of the inorganic portions of their remains range from a fraction of 1 percent for some corals to nearly 16 percent in alcyonarians and some crustaceans. Analyses of globigerina ooze and pteropod ooze also show only small amounts of $MgCO_3$, around 1 percent or less.

The fossil evidence found in the high-calcium limestones of east-central California has been too meager to be of much assistance in determining the type of organism from which the deposits were derived. Only a few crinoids have been found. The limestone and the surrounding formations have been subjected to heavy compressive stresses, which is usually considered the cause of the obliteration of organic remains. The proof of organic origin of the limestone remains in the fact that practically every sample taken gives a fetid odor when struck by the hammer, even in cases where analysis shows 98 to 99 percent $CaCO_3$. The uncombined carbon content is very low, though often sufficient to give the stone a gray color, ranging from dove color to near black.

There appears to be an interesting geographic separation of limestones according to calcium-magnesium ratio along the Sierra Nevada front, which is probably a matter of difference in geologic age. Magnesian limestone is much the commoner from Calaveras County southward. From Amador County northward, high-calcium limestone predominates. The most extensive exposures are in Tuolumne County, and most analyses of samples taken there for this report show a magnesium content, but not sufficient to justify the name dolomite. In one case, however, where a width of 900 feet was sampled, it was possible to distinguish between the high-calcium and dolomitic beds accurately enough to cut separate samples showing on one side 600 feet of high-calcium limestone with less than 3 percent magnesium carbonate, and on the other 300 feet showing 35.46 percent $MgCO_3$ and 60.77 percent $CaCO_3$. This abrupt transition is difficult to explain as the beds appear to be in contact. However, it is no

more remarkable than the abrupt change in the composition of core samples taken by drilling coral and coral rock on the atoll of Funafuti. In that case, the analyses of drill cores taken at depths from 55 to 598 feet yielded $MgCO_3$ ranging from 0.79 to 5.85 percent, with only 1.06 percent $MgCO_3$ at 598 feet. The sample from a depth of 640 feet contained 26.33 percent $MgCO_3$ and from there to a depth of 1114 feet the content of $MgCO_3$ was about 40 percent. At Funafuti, the principal organisms which contributed to the building of the atoll were, in the order of abundance, (1) Lithothamnion (algae); (2) Halimeda (jointed green algae); (3) Foraminifera; (4) Corals.

The deposit in Tuolumne County and adjacent Calaveras County is exceptionally large probably because a combination of geological circumstances have preserved it. In the place where the above 600-foot and 300-foot samples were taken, the beds have been folded into an almost vertical position and the folds have then been truncated by erosion along Blanket Creek, in such a way as to expose the lower and older dolomitic limestone on the south. The cause of the folding was the intrusion of a batholith directly to the north, but actual proof of folding, which would be the finding of the strata repeated to the south, is concealed by detritus in the valley of Blanket Creek. On the north, the extent of erosion is controlled by a reef of hard buff and pink quartzite.

On the Sierra Nevada slopes in Mariposa, Madera, and Fresno Counties there are fewer accessible limestone deposits than farther north, and the only important development has been the opening of a quarry on a large high-calcium deposit on the north side of Merced River, 3 miles northwest of Clearinghouse. This stone was hauled over the Yosemite Valley Railroad to Merced to make portland cement, but the cement plant has recently been removed.

The Mother Lode gold belt (Jurassic) is terminated near the town of Mariposa and from there southward geologic mapping has been only fragmentary. The granite and related deep-seated rocks of the Sierra Nevada batholith become more prominent and turn nearer south, as erosion of the overlying rocks (slate, schist, shale, and sandstone) has been more active than farther north. In Madera, Fresno, and Tulare Counties many small limestone deposits have been noted on or near granitic contacts, where metamorphism has resulted in the formation of numerous small deposits of scheelite ore. These deposits are generally too remote from transportation, too small in tonnage, or too impure because of contact metamorphism to be of commercial value except possibly as a source of tungsten.

In Tulare County the limestone which is near enough to railroads to be of interest is mostly different in character from that farther north. It represents the bottom zone, and occurs as roof pendants on the granitic rocks. It therefore shows greater variation in crystal size and a wider range in chemical composition due to localized, contact metamorphism, not only from the granite but from later intrusives.

Limestone deposits near Tehachapi in Kern County for a long time supplied the southern California market. They are generally coarsely crystalline, occur on the granite and with interbedded schists and probably represent remnants of once much larger deposits. Except for one large deposit a few miles east of Tehachapi, which has been worked to make cement, no limestone or lime has been produced in Kern County

since 1928. The Garlock fault, striking northeast a few miles south of Tehachapi, is recognized as the southern boundary of the Sierra Nevada geomorphic province.

Northern California

Northern California north of the Sacramento Valley is divided into three principal geomorphic provinces. The western half, occupied by the Klamath Mountains and the Cascade Ranges is more important economically. The eastern half is covered by barren young volcanic rocks of the Modoc Plateau, and on the west by similar material from Lassen Peak and Mount Shasta. The remaining area of older crystalline rocks contains large limestone deposits of Devonian, Permian, and Triassic age. Shasta County contains most of these deposits that are near a railroad, and some of them have been worked in past years, though not recently active. Of the numerous deposits in Siskiyou County, only a few are near enough to a railroad to be of economic importance at present. One such deposit has been worked within the past 2 years.

The Shasta County deposits are in a thinly populated region where there is not much local demand. The more populous parts of Sacramento Valley are 125 to 200 miles distant. The nearest lime kiln is in El Dorado County 50 miles east of Sacramento or about 250 miles from Redding. There are immense undeveloped deposits of lignite within a few miles of the limestone, and cheap electric power is produced at Shasta Dam also near the limestone beds. With such a combination of resources, and with the population of the state increasing, these limestone deposits appear to have interesting future possibilities.

The Desert Region

Mojave Desert covers most of San Bernardino County, the eastern half of Riverside County and parts of Kern and Los Angeles Counties. The northern portion contains part of the Great Basin; its boundary is indefinite. The southern portion includes the Colorado Desert, and probably should include the entire portion of California east of the Sierra Nevada as far north as northern Mono County, and east of Cajon Pass and the San Jacinto fault to the Mexican line, (except for the land draining directly into Colorado River); for this is a land of interior drainage and limited rainfall, which fulfills the definition of a desert. Imperial County and northeastern San Diego County fall within this area.

In this vast and sparsely inhabited region there are immense deposits of hard limestone, marble, and dolomite. San Bernardino County, larger than several of the Atlantic states combined, has many such deposits within reasonable distance of the two transcontinental railroads which cross it. Several thousand miles of dirt roads and state highways serve all parts of the county. The deposits range in age from Paleozoic (probably Carboniferous) in the west to Middle and Lower Cambrian. The older deposits are usually roof pendants on granite or related deep-seated intrusives. Dolomite is also of frequent occurrence.

The most extensive dolomite deposits in the state are in Inyo County in the Death Valley region, and the only use so far made of them has been for marble and in a local chemical plant. They range in age from the Lower Cambrian Noonday dolomite, 1500 feet thick, through Middle Cambrian beds 5182 feet thick (mostly dolomite), Upper Cambrian, Lower and Upper Ordovician.

Imperial County also contains several undeveloped limestone deposits which are not too far from railroad. The natural market for these and for deposits in eastern San Diego County would be in the city of San Diego.

Peninsular and Transverse Ranges

These geomorphic provinces embrace the more populous sections of southern California, including the larger parts of Ventura and Los Angeles Counties, all of Orange and San Diego Counties and the important western parts of San Bernardino and Riverside Counties. In proportion to population and industries which require lime and limestone, this region has relatively few good deposits and has been supplied largely from other California districts and from Nevada and Arizona deposits. There is one portland cement plant in Riverside County and one in Los Angeles County, but the latter uses clinker made outside the county. In late years there has been only one producer of limestone in each of the counties of Los Angeles, Riverside, and Ventura, and there has been no recorded production from Orange and San Diego Counties. Central San Diego County contains several deposits of hard limestone and marble (probably Triassic) but along the coast only marl or other soft fossiliferous limestone has been produced. There is one good-sized undeveloped deposit of Paleocene algal limestone in Los Angeles County. The important limestone deposits of southwestern San Bernardino County which support portland cement plants at Colton, Victorville, and Oro Grande are in the border zone where the Mojave Desert approaches the coast.

The Great Valley

The central valley of California is about 400 miles long and from 35 to 65 miles wide, extending from the upper Sacramento River in Shasta County to southern Kern County. Most of this great area is covered by alluvium devoid of economic mineral deposits except sand and gravel. In the older sediments fringing both sides of the valley some deposits of marl have been noted. There has been little development of these deposits because they would be suitable principally for local use as fertilizer or soil corrective, and no great need has appeared for them so far. Ultimately, in regions of more than average rainfall and with good drainage, and especially where legumes are raised, such a need will develope. This will be in the Sacramento Valley, where a few sales of marl from Nevada have already been reported. In the southern or San Joaquin Valley, because of scantier rainfall and poorer drainage, calcium carbonate has been retained in the soil, and further addition is not necessary. Gypsum is being used in great quantity in that region, principally for its sulfur content.

The only commercial production of marl in the Great Valley has been in Fresno County, where output was reported between 1931 and 1939.

Coast Ranges

Exploitation of limestone in the Coast Ranges has in general been confined to the region within 100 miles of San Francisco, and except for the travertine of Solano, Contra Costa, and Napa Counties, which has been used to make portland cement, most of the production has come

from south of the bay. The deposits vary widely in age and character, from Recent oyster and other shells being dredged from the bay in San Mateo County for making cement, to the limestones and dolomites believed to be the oldest rocks of the Coast Ranges. Santa Cruz County produces much limestone, while Monterey and San Benito Counties have done so in the past. The dolomite deposits in Monterey County which were worked during the last war, and the adjoining dolomite and associated limestone of the Gabilan Mountains in San Benito County are roof pendants on granitic rocks. Santa Clara County has produced marl and shells and lately has been providing limestone for a large portland cement plant. About 200 miles south of San Francisco in San Luis Obispo County are large beds of limestone derived from shells; these have been used for beet sugar refining. In this county also are beds of oyster shells. The boundary of the Coast Range geomorphic province in this direction lies in southern Santa Barbara County.

North of San Francisco in the Coast Range province there has been little limestone produced and there is evidently a lack of notably large deposits.

Alameda County

The geology of the western part of Alameda County has been mapped in the San Francisco, Concord, and Hayward quadrangles (Lawson, A. C. 14). Freshwater limestone occurs sparingly in the Orinda, Moraga, and Siesta formations (Pliocene) but in such small deposits in this county that most of them are not shown on the map. One small body on the county line about three-quarters of a mile south of Grizzly Peak is at the contact between the Moraga and Siesta beds. In a paper by Lawson and Palache, (02, pp. 383, 388), these deposits (principally in Contra Costa County) are described as "compact, light gray rocks of uniform texture. . . . Locally they contain numerous detrital fragments indicating a shallow-water origin for the deposit. They can scarcely be regarded as other than chemically-precipitated deposits although the conditions which determined the precipitation cannot be stated positively."

Some small travertine deposits from mineral springs were noted in the Berkeley Hills north of Berkeley but were not shown on the geologic map as they were believed to have been moved by landslides, and not in their original positions. So far as known, such deposits have not been worked in Alameda County. Geologically, they are of the Recent series.

The earliest lime production in the county was made at Mission San Jose, until the local supply of wood fuel was exhausted. Later this locality furnished some marl for agricultural use. There has also been a small production of limestone and lime from a deposit midway between Sunol and Pleasanton. More important than any other deposits in the county are the beds of oyster shells in the southern arm of San Francisco Bay. From 1931 to 1936 California Chemical Corporation and its successor, California Chemical Company, produced lime and shells at their Newark plant. In 1936 the latter company was succeeded by Westvaco Chlorine Products Company who built a plant in 1938 reported to have cost $1,500,000. Sea-water bittern from salt works and oyster shells from the bay are used to make magnesite. Bromine, chemical lime, shells, and gypsum are also produced.

Collins deposit is reported to show a small outcrop of crystalline limestone on a hilltop in sec. 30, T. 2 S., R. 3 E., M. D. a mile or more southwest of Altamont. There is no record of work on it.

McLaughlin lithographic-stone quarry is in SW¼ SW¼ sec. 35, T. 1 S., R. 2 W., M.D., close to the Contra Costa County line. It is about 8 miles north of Hayward by the Cull Canyon road.

This quarry (Laizure, C. McK. 29, pp. 433-434) was opened about 1905, exposing a vein about 5 feet thick for 25 feet along the strike. A test by Schmidt Lithographing Company indicated it might be used for ''penning'', in which the design is painted on the stone instead of being cut. The stone exposed by the shallow work had some properties of a good lithographic stone but was not quite fine-grained and uniform enough for engraving. So far as known no recent work has been done on it. The outcrop extends for 570 feet, striking northwest.

Mission lime marl deposit is about a quarter of a mile east of Mission San Jose and outcrops at the base of a small hill, where some work has been done in an open cut. Other exposures nearby are reported. Although some production was made years ago, the property has not produced during the past 20 years.

	Percent
Nitrogen	0.46
Calcium carbonate	83.10
Lime phosphate	0.59
Potash (soluble)	0.46
Undetermined	15.39

Pleasanton deposit is midway between Sunol and Pleasanton on the Western Pacific Railroad. Some lime was burned there about 20 years ago and sold for use on land. No production has been reported in recent years.

Alpine County

Alpine County is so thinly populated (323 people in 1940), and so remote from population centers that ordinary limestone within its boundaries would have slight value. The exposed geologic formations are principally the granitic rock of the Sierra Nevada batholith, and later effusive volcanic material, which is mostly andesite.

Grovers Hot Springs Deposit. These springs are 4.2 miles by road west of Markleeville, close to a north-striking fault that has been traced into Nevada. Two groups of springs having temperatures a few years ago ranging from 128° F. to 146° F. issue from a terrace on the edge of a meadow 200 to 300 yards south of Markleeville Creek. In 1920 the combined flow from 12 springs was about 12 miner's inches, and part of it has been used for bathing. The accumulation of calcareous tufa, is still going on. An analysis of the water by Laird J. Stabeler showed the following, in grains per U. S. gallon:

NaCl	19.91
Na_2SO_4	12.02
Na_2CO_3	34.10
$CaCO_3$	6.38
$MgCO_3$	1.16
Silica	0.82
Fe and Al	0.32
Organic matter	Trace

In a discussion of deposits of calcium carbonate from springs of this character, Waring (15, p. 154) theorizes that where there is considerable carbon dioxide, sodium, and magnesium, with a smaller amount of calcium present in the water, the deposition of the calcium carbonate is caused by the sodium and magnesium depriving the calcium of bicarbonate. While he mentions lava nearby as a possible source at this and similar springs elsewhere, the marked fault mentioned above must also be considered in this case.

Amador County

The limestone deposits of Amador County lie in two areas where the exposed formations were mapped many years ago by the U. S. Geological Survey under the name Calaveras, and were placed in the Carboniferous, principally on the evidence of a limited number of fossils found in the limestone. On the new State geologic map of California published by the State Division of Mines, the Calaveras is placed in the lower Carboniferous as ''Missippian marine metasediments.'' The term Calaveras has long been known among geologists and engineers as an unsatisfactory catchall for a number of formations which needed further geologic differentiation, but very little has ever been published to indicate that work has been done on the problem since the issuance of the Gold Belt folios. N. L. Taliaferro (43, p. 280) of the Department of Geologic Sciences of the University of California, has lately alluded briefly to the subject as follows (see also discussion under *Shasta County*):

"South of the Taylorsville region all the Paleozoic rocks, even where subdivided into formations, have been placed in the Calaveras group and assigned to the Carboniferous, generally on far from satisfactory evidence. Practically all of the fossils found have come from lenses of limestone; because of the recrystallization of the limestone the preservation is poor. Notwithstanding the fact that the fossils, in the great majority of cases, indicate nothing more than a Paleozoic age, the Calaveras invariably is stated to be Carboniferous on the legends of the various geologic maps of the Sierra Nevada. Undoubtedly the Carboniferous is represented, but the writer is of the opinion that at least a part of the Calaveras is Permian and a part pre-Carboniferous."

The limestone deposits in the low western foothill region of the county are numerous and small in size. They vary in composition from a high-calcium limestone to highly magnesian limestone close to dolomite. These deposits have been worked only on a limited scale and have produced some limestone, lime, and marble. Farther east, at Volcano and east of Fiddletown are two large deposits, the one at Volcano being a high-calcium limestone comparing favorably with the best in the state. This deposit, and part of the one farther north formed the bedrock of an ancient stream. When this stream was clogged by volcanic debris and ceased to function, the gravel and andesite protected the limestone so that it escaped the entire period of erosion since Tertiary time. It was finally exposed by hydraulic mining. Except for some marble production west of Volcano, deposits in that region have remained undeveloped because of their distance from railroads.

The total production of lime and limestone from the county has not been recorded, but from 1904 to 1916 amounted to 12,640 barrels of lime and over 4000 tons of limestone. The value of marble produced during the same period was over $100,000. Later output of marble from a single quarry was not published.

Allen Estate is held by George Allen, Sutter Creek. This is a large property devoted to grazing, lying east and northeast of Ione. Beginning in sec. 3, T. 6 N., R. 10 E., M. D., 7 miles northeast of Ione by road, and occurring at intervals going south to within a short distance of the Amador Central Railroad there are a number of limestone outcrops on this land, but only a few of those seen were large enough to offer promise. One of the latter from which a sample was taken for analysis in 1944 has a maximum width at the surface of 150 feet and the main body is about 350 feet long, but limestone outcrops at intervals for 1800 feet along the strike (north-northwest) and trenching or drilling might reveal more than is now indicated by outcrops. The limestone is gray, with medium crystals but compact and tough. Backs of about 100 feet could be had.

The report of analysis by Abbot A. Hanks, Inc., was as follows:

	Percent
Insoluble	1.60
Ferric and aluminic oxides	0.42
Calcium carbonate	96.90
Magnesium carbonate	1.06

Only a little surface prospecting had been done.

Late in 1945, A. Teichert and Son, Inc., 1846 Thirty-seventh Street, Sacramento, began work on a similar outcrop on this property 1½ miles north of the line of the Amador Central Railroad. Lump limestone was mined from surface workings, crushed to about 6-inch size and hauled under contract to a nearby railroad spur track east of Ione. Here it was dumped directly from the trucks into gondola cars for shipment to sugar factories.

Amador Lime Rock Deposit. Address Culbert Estate, c/o Ralph McGee, Jackson, California. Located in sec. 16, T. 6 N., R. 10 E., M. D., 4 miles northeast of Ione.

This deposit was worked in a small way from 1859 to 1910. Evidently a large part of the limestone burned in the old style pot kiln was gathered from the surface, as only shallow pits are to be seen. Much of the present deposit was removed by erosion, and backs at present available would be limited due to the gentle slopes. It would be necessary to sink a shaft to obtain any more than a small tonnage. There are two exposures of a good grade of limestone, each 85 feet wide; and along the strike, but not continuously exposed, this grade of stone was traced for 700 feet. On a hill a quarter of a mile distant is another outcrop, 45 feet by 150 feet, which is quite siliceous.

An analysis of limestone from this property was quoted in 1912 by Burchard (12, p. 660), which showed 97.78 percent $CaCO_3$. It is a light gray, compact, finely crystalline stone.

Blakely and/or *Garibaldi Ranches.* Located in N½ sec. 33, T. 7 N., R. 10 E, M.D. As no one was in the region to point out property lines at the time of visit, and time was not taken to determine these, the writer is uncertain as to ownership of deposit. It is 2½ miles from Drytown and 7 miles by road from the railroad at Ione.

The main outcrop strikes N. 30° W. and is continuous for a width of 120 feet and a length of 930 feet. It is likely that a little stripping

would reveal a maximum width of 260 feet, as the stone outcrops at intervals for that width. Backs of 50 feet could be had for nearly the entire length by running cuts eastward for about 135 feet from the valley west of deposit. No work has been done.

This deposit is a rather hard, tough gray magnesian limestone, quite different physically and chemically from the high-calcium limestones common in the region. A sample was taken across a width of 120 feet and the following analysis was reported by Abbot A. Hanks, Inc.:

	Percent
Insoluble	3.55
Ferric oxide and aluminic oxide	0.30
Calcium carbonate	71.70
Magnesium carbonate	24.31
	99.86

Closer investigation, which is impossible without some trenching and sampling of separate sections, might indicate the presence of bands of dolomite. About a mile of road would be needed for hauling.

Dal Porto marble (Amador or *Oleta marble quarry)* was worked in 1888 or earlier and has produced considerable marble, but has been idle in recent years. Address Allessio dal Porto, Plymouth. It is a patented placer claim, being the S½SW¼ and SW¼SE¼ sec. 6, T. 7 N., R. 11 E. M. D. It is 2½ miles east of Plymouth and 13 miles by good road northeast of Carbondale.

A quarry face 90 feet wide was opened 20 feet above the small stream which crosses the deposit; a waste dump 200 feet long and 40 feet wide at the base indicates considerable dead work. The best marble is in a width of 50 feet in the center. The deposit is an upright lens in the Calaveras meta-sediments just east of a granitic contact. The color of the marble varies from white to dark gray, with some attractively veined material.

On the north side of the Plymouth-Fiddletown road, a quarter of a mile north and 200 feet higher than the quarry floor, the marble was exposed by road work, and shows a width of 100 feet.

Analysis of a sample taken across the quarry face was made by Abbot A. Hanks, Inc., with the following results:

	Percent
Insoluble	5.59
Ferric oxide and aluminic oxide	0.56
Calcium carbonate	90.69
Magnesium carbonate	2.04
	98.88

Dondero (Carrara) marble quarry is in N½ sec. 29, T. 7 N., R. 12 E., M. D., 2¼ miles from Volcano and 12 miles by road from Martell railroad station. It is on the south side of the canyon of Sutter Creek, and its position permitted cheap operation. A quarry floor 150 feet wide was opened and when last visited the face was nearly that high. Production on a modest scale extended over 30 years, and the marble was used in many buildings in San Francisco. C. Dondero worked the quarry in the dry season until 1933, since when no production has been reported. Good-sized blocks were shipped in the rough state to a yard at San Francisco where they were cut and polished.

The stone in the main quarry is principally a white marble, irregularly veined with blue, but some white and ash-colored stone was also produced.

Ellis Brothers Ranch is owned by J. M. and F. J. Ellis, Box 326, Jackson. Outcrops of a good grade of limestone occur on this land in sec. 30, T. 6 N., R. 11 E., M. D., about 3 miles west of Jackson; also on land under the same ownership 3 miles farther south, and 0.6 of a mile east of the county road. The latter is the larger outcrop, being about 120 by 75 feet. No work has been done upon it.

Other small outcrops of limestone occur on land held by East Bay Utilities District south of the deposit of the Ellis brothers. These outcrops were not accessible on account of locked gates.

Fiddletown deposit is owned by the Pacific Portland Cement Company, 417 Montgomery Street, San Francisco. The company has 520 acres in secs. 5, 6, and 7, T. 7 N., R. 12 E., M. D., 12½ miles northeast of Martell railroad station by road and at an elevation of 2000 to 2300 feet. This land contains a large part of the large and irregular outcrops of limestone 4 miles east of Fiddletown, on the old McCormick Ranch.

The deposit is partly covered by andesite and gravel, and partly by soil, so that the full extent could only be determined by drilling. What is probably the largest continuous outcrop was followed for half a mile west to east and for 500 feet from north to south. This part is a soft, easily fractured, saccharoid limestone, dark gray to pure white in color, and generally showing narrow, gray stripes. Outcrops along the flat south side rise scarcely 1 or 2 feet above the surface. The north end is covered for 1000 feet by andesite; the highest outcrop is at 2283 feet, allowing maximum backs of 150 feet in this part of deposit.

On the south in section 7 there are several flat, separate outcrops probably linked underground. Toward the east these lead to an area of old placer workings where the eroded limestone has been exposed for a width of 500 feet.

A sample taken across the first-mentioned section, 500 feet north to south, gave the following analysis by Abbot A. Hanks, Inc., August 23, 1943:

	Percent
Insoluble	0.60
Ferric oxide and aluminic oxide	0.22
Calcium carbonate	95.31
Magnesium carbonate	2.98
	99.11

This deposit, which is entirely undeveloped, would yield many millions of tons, as the single exposure first described would produce approximately 100,000 tons per foot in depth. However, it is comparatively distant from railroad and may not be opened for many years.

Garibaldi Ranch. Address Theresa Garibaldi, Amador City. Some small outcrops of good-grade gray crystalline limestone were noted probably in the NE¼ sec. 3, T. 6 N., R. 10 E., M. D., less than half a mile north of Horse Creek. Those seen were not large enough to warrant sampling, but trenching might reveal more.

A, CARRARA (DONDERO) MARBLE QUARRY
Near Pine Grove, Amador County.

B, LIMESTONE EXPOSED NORTH OF VOLCANO, PLACER COUNTY
BY PLACER MINING.

4—74191

AUBURN LIME PRODUCTS COMPANY PLANT

Near Rattlesnake Bar, El Dorado County. Part of old quarry on hill in background. *Photo by courtesy of Auburn Lime Products Company.*

A, LOADING LIMESTONE
California Rock and Gravel Company's Cave Valley limestone deposit near Cool, El Dorado County.

B, CALIFORNIA ROCK AND GRAVEL COMPANY PLANT
Cowell Cave Valley limestone deposit near Cool, El Dorado County, October 1946.

DIAMOND SPRINGS LIME COMPANY PLANT

At Diamond Springs, El Dorado County. *Photo by courtesy of Diamond Springs Lime Company.*

LIMESTONE QUARRY
Diamond Springs Lime Company, El Dorado County.
Photo by courtesy of Diamond Springs Lime Company.

A, HEADFRAME, AND CRUSHING AND LOADING PLANT
El Dorado Limestone Company, El Dorado County.

B, INDIAN DIGGINGS LIMESTONE DEPOSIT, EL DORADO COUNTY.

A, REMAINDER OF LIMESTONE OUTCROP

Mountain Quarries deposit near Cool, El Dorado County. Glory holes in this deposit supplied limestone at the rate of more than 1,000 tons daily for many years.

B, TOP OF GLORY HOLE

Mountain quarry of Pacific Portland Cement Company. A diabase dike 5 to 6 feet wide (marked "x") intrudes the limestone (left side of photograph).

A, PART OF OUTCROP

O'Brien limestone deposit near Briceburg, Mariposa County. *Photo by courtesy of Ethel R. O'Brien.*

B, PERMANENTE METALS CORPORATION DOLOMITE QUARRY

Near Natividad School, Monterey County.

PERMANENTE LIMESTONE

Generators driven by a system of gravity flow conveyor belts produce enough electricity to operate the 5-yard shovel used to excavate limestone in Permanente Cement Company's quarry. *Photo by courtesy of Permanente Cement Company.*

PERMANENTE LIMESTONE

Limestone starts the mile-long journey, by way of conveyor belt, from the Permanente Cement Company quarry, Santa Clara County, to the processing plant. Buggies like the one pictured above are 25-yard capacity. The plant uses more than 4 miles of conveyor belting by which rock moves downhill at the rate of 1000 tons per hour.

Photo by courtesy of Permanente Cement Company.

CIMA LIMESTONE DEPOSIT, SAN BERNARDINO COUNTY.
Photo by courtesy of James Vernon.

A, FACE OF LIMESTONE

Lamb Bros. limestone deposit, San Bernardino County. *Photo by courtesy of John Gaarden.*

B, LOWER QUARRY

Vaughan Marble Company, Cadiz, San Bernardino County. *Photo by courtesy of Vaughan Marble Company.*

MARBLE MOUNTAIN
Site of upper quarry of Vaughan Marble Company near Cadiz, San Bernardino County.
Photo by courtesy of Vaughan Marble Company.

A, NEW QUARRY

Lime Mountain limestone deposit, San Luis Obispo County. Apex is 100 feet above quarry floor.

B, ROCKAWAY LIMESTONE QUARRY

Rockaway Beach, San Mateo County. *Photo by courtesy of Henry H. Symons.*

C, PANORAMIC VIEW OF McCLOUD LIMESTONE

Near Baird, Shasta County. Shasta Dam in foreground. Looking east from state highway.

A, BLOSSOM PEAK LIMESTONE DEPOSIT
Near Three Rivers, Tulare County. Peak is 700 feet above camera level.

B, RIVERSIDE CEMENT COMPANY LIMESTONE DEPOSIT
Sec. 29, T. 20 S., R. 31 E., M.D., east of Moorehouse Creek, Tulare County.

A, OLD MARBLE QUARRY
Formerly worked by Columbia Marble Company, Tuolumne County.

B, PART OF ROTARY KILN, AND DUST CONDENSER
U.S. Lime Products Company, Sonora, Tuolumne County.

Grelich Ranch. Address Edward Grelich, Drytown. In secs. 5 and 8, T. 7 N., R. 10 E., M. W., 8 miles southeast of Latrobe (on Southern Pacific Railroad) by good road.

The principal outcrop is 450 feet long by 50 feet wide on the north end, and 85 feet wide on the south. Another is 130 feet long, and smaller ones were noted. The outcrops are low and inconspicuous, and as there is considerable valley land along the strike, which shows no other rock outcrops, much of the deposit may be covered by soil, and it may extend into land owned by others. Some small outcrops were noted on the SW$\frac{1}{4}$ sec. 5, owned by *F. H. White.*

The limestone is apparently good grade, finely crystalline and gray in color. It is entirely undeveloped. It lies so that sinking would be required to work it. Following is an analysis by Abbot A. Hanks, Inc.:

	Percent
Insoluble	1.00
Fe_2O_3 and Al_2O_3	0.56
$CaCO_3$	97.85
$MgCO_3$	0.41

Clarence Scully, Ione, owns land west and southwest of Jackson on which limestone is reported. This is north of the Ellis brothers' ranch.

Volcano limestone deposit is owned by Great Western Land Development Company, which is reported to be fully owned by F. L. Smidth and Company, 60 East 42nd Street, New York and Copenhagen, Denmark. The 825 acres owned outright and mineral rights on about 520 acres more, cover most of the large limestone deposit at and near Volcano, which is 15 miles from Martell, the nearest railroad shipping point. The elevation is from 2000 feet to 2500 feet extending from Sutter Creek to the hills on both sides.

In 1928, when the properties were offered to the present owners, six deep diamond-drill holes were put down in the deposit and hundreds of samples were sent out for analysis. The results are said to have been satisfactory enough to warrant completion of the purchase. Plans were made for erecting a Portland cement plant in Sacramento Valley and a right-of-way for a branch railroad from Volcano to the valley, following Sutter Creek, was purchased. The panic of 1929 interrupted the work, and nothing has been done since.

This is probably the largest high-calcium, low-magnesium limestone deposit in the region, (though it does not compare in size with the magnesian limestone beds of Calaveras and Tuolumne Counties). Maximum backs of 300 feet or more from the level of the main street of Volcano northward are indicated by outcrops and exposures of limestone bedrock in old placer workings over a distance of a mile and a width of half a mile. South of Volcano, the limestone extends 1$\frac{1}{2}$ miles but is much narrower; however, a very substantial tonnage lies there, much of it having backs of 250 to 300 feet. An area of limestone half a mile square contains over 580,000 tons for each foot in depth.

A sample of diamond-drill core marked "Hole 3, 230 to 235 ft.," which in this case would mean a vertical depth of 115 feet, was analyzed by Abbot A. Hanks, Inc., with the following results:

	Percent
Insoluble	0.22
Ferric oxide and aluminic oxide	0.19
Calcium carbonate	99.03
Magnesium carbonate	0.37
	99.81

A surface sample taken by the writer at intervals over a distance of half a mile north of the town, and also analyzed by Hanks, gave the following:

	Percent
Insoluble	1.16
Fe_2O_3 and Al_2O_3	0.37
Calcium carbonate	97.26
Magnesium carbonate	0.39
	99.18

The reason for the large areal extent of the limestone here (and also in the Fiddletown deposit farther north) is believed to be that the deposits have been partially protected from modern erosion by coverings of Tertiary gravel and volcanic debris.

Wait marble deposit is owned by A. L. Wait. It is near the state highway 8 miles north of Carbondale railway station by good road and close to Wait's Station.

This deposit received favorable mention in the fourth (Hanks, H. G. 84, p. 108) and sixth (Hanks, H. G. 86, pp. 22-23) reports of the State Mineralogist, and in the latter was described as "roseo antico" from its similarity to a marble of that name which was highly regarded by the ancient Romans. In that report its specific gravity is given as 2.828, its hardness as 3. It is a hard and durable stone and takes a high polish, having a beautiful cherry-red color due to iron compounds. It outcrops over an area of 160 by 400 feet and the surface is flat. The only work done on it is a drill hole said to be 46 feet deep, which was drilled in 1924. This is claimed to be entirely in the marble.

Nearby there is a small outcrop of the "verde antique" type of stone, serpentine veined with magnesite. Nothing has been done on this.

Butte County

The limestone deposits of Butte County were mentioned in the report of the Geological Survey of California (Whitney, J. D. 65, pp. 209-212). This alludes briefly to the Pence's Ranch (now Pentz) limestone, saying that portions of it would make good gray marble and the lime burned from it is of good quality.

In the same report (p. 210), it is stated that

> "The fossils found in these limestones, although imperfect, are sufficient to identify them as of the same age as those of Bass's Ranch (Shasta County, see Redding folio, U. S. Geol. Survey) which are pronounced by Mr. Meek to be carboniferous. *Productus semireticulatus* and *Spirifer lineatus* were recognized by Mr. Gabb and a portion of the rock is made up of the stems of crinoids, too much obliterated to allow of their generic relations being made out."

The reader should consider what has been published in late years about the age of the limestones called "Carboniferous" by the first geological survey, and by geologists in general up to 12 years ago. Reference

to recent work by Norman E. A. Hinds of the University of California and H. E. Wheeler of Stanford University, placing the McCloud limestone in the Permian, is made herein under Shasta County. Their findings may bear directly on the age of much of the limestone in the Sierra Nevada.

The limestone in Butte County has been exploited in only a small way to make lime for local use and shipments to outside points were made for one or two seasons from deposits in Feather River Canyon. However, the deposits in the Pentz region were investigated nearly 40 years ago by Whitman Symmes and later by Robert J. Burgess, to determine their suitability as sources of limestone and shale for a Portland cement plant. The writer is indebted to the latter especially for information on the Arlington, Marysville, Parish and Wilson deposits, and for analyses made by the late Professor W. C. Blasdale of the state university, and others.

Deposits on or near the North Fork of Feather River and close to the Western Pacific Railroad are now the most accessible in the county and could supply local demands.

Arlington group is assessed to Arlington Properties Company, c/o Pacific Gas & Electric Company, 245 Market Street, San Francisco. For the purposes of this report, a number of limestone deposits in the vicinity of Nelson Bar bridge, and not far from the Pentz-Nelson Bar-Yankee Hill road, have been grouped under this name. Although this bridge is only 2 miles from the Western Pacific Railroad, the intervening country is rough and steep, and there is no road connection. Oroville is from 15 miles to 17½ miles south. At different times, these deposits and some others mentioned hereafter in this report, have been examined and sampled with the idea of making them the source of supply for a Portland cement plant. With the exception of some lime production years ago from the present Arlington No. 1 and the Parish deposits, the only work done upon them has been a little prospecting for marble in the NW¼ sec. 8, T. 21 N., R. 4 E., M. D.

Arlington No. 1 (formerly *Hodapp* or *Curtis)* is in NW¼ sec. 8, T. 21 N., R. 4 E., about a quarter of a mile east of Nelson Bar bridge at an elevation of 900 feet and close to the Pentz-Yankee Hill road. This is probably the largest deposit of the district, with about 1,000,000 tons claimed in sight and much more probable. The analyses indicate a rather siliceous limestone with appreciable amounts of MgO.

There is considerable variation in analyses, however, as indicated by the following:

Analysis by Smith Emery & Company

	Percent
SiO_2	0.48
Al_2O_3	0.21
Fe_2O_3	0.39
CaO	54.48
MgO	2.97

Analysis by Prof. W. C. Blasdale

	Percent
SiO_2	7.38
Al_2O_3	3.59
Fe_2O_3	1.68
CaO	45.00
MgO	2.79

Arlington No. 2 (formerly *Durbrow)* is a small deposit, perhaps less than 100,000 tons. It is in sec. 8, T. 21 N., R. 4 E. at an elevation of about 500 feet near the West Branch of Feather River. An analysis by Prof. W. C. Blasdale gave:

	Percent
SiO_2	2.12
Al_2O_3	0.54
Fe_2O_3	none
CaO	52.46
MgO	1.94

Arlington No. 3 (formerly *Nix)* in SE¼ sec. 8, T. 21 N., R. 4 E., half a mile from the West Branch and about three-quarters of a mile from either of two roads to Pentz. There are several small lenses of limestone on this quarter-section. If they remain of the same cross-section areas to a depth of 100 feet as are shown at the surface, they may contain 800,000 tons to that depth.

Two analyses indicate 96 percent $CaCO_3$, 1 percent each of Al_2O_3 and MgO, and less than 1 percent SiO_2.

Arlington No. 4 (also called *Cliffs No. 2*) is in the N½SW¼ sec. 17, T. 21 N., R. 4 E., at an elevation of 600 feet on west side of West Branch of Feather River. The area of limestone on the surface is nearly an acre and if the cross-section remains of equal size to a depth of 100 feet it would give about 340,000 tons. Analyses by Smith Emery & Company and Professor W. C. Blasdale give the following ranges:

From 89. 6% to 95. 6% $CaCO_3$
From 2.18% to 6.28% SiO_2
From 0.08% to 1.02% Fe_2O_3
From 0.35% to 0.82% Al_2O_3
From 0.12% to 1.33% MgO

Arlington No. 5 (also called *Cliffs No. 1)* is just west of West Branch of Feather River, in SE¼ sec. 17, T. 21 N., R. 4 E., at an elevation of 600 feet. There are several lenses of limestone in this quarter section. If they maintain to a depth of 100 feet the same dimensions shown at the surface, they would contain about 380,000 tons.

Analyses quoted by Burgess show the following ranges of variation:

SiO_2 from 0.78 to 12.14%
Al_2O_3 from 0.39 to 1. 9%
Fe_2O_3 from 0.04 to 1.16%
MgO from 0.10 to 0.54%
$CaCO_3$ from 84.00 to 98.00%

Big Bend marble quarry is located in sec. 32, T. 22 N., R. 5 E., M. D., (Aubury, L. E. 06, p. 98). Until the Western Pacific Railroad was built, this land could be reached only by trail, but is now close to the railroad line. Some limestone was shipped from here in 1929 (see *McLean limestone*). One lens of limestone, blue and said to take a high polish, crosses the river and extends southeast for some distance. Another, of white marble, is reported northeast of the first.

Marysville Limestone. The Marysville deposit is owned by Pacific Gas & Electric Company and Arlington Properties Company, 245 Market Street, San Francisco. It is in secs. 7 and 18, T. 21 N., R. 4 E., 350 feet above the West Branch of Feather River and a quarter of a mile west of it, and about three-eighths of a mile from the road.

This is a small lens of limestone, partly covered on the north end by lava. It is claimed that there are about 150,000 tons "in sight." Judging from the following analysis by Professor W. C. Blasdale, it is of very good quality:

	Percent
SiO_2	0.23
Al_2O_3	0.36
Fe_2O_3	0.10
CaO	54.62
MgO	0.52
Loss on ignition	43.69
CO_2	43.31
Purity as $CaCO_3$	97.50

McLean limestone is assessed to Anna Grant McLean, San Francisco. It is on patented mineral land in sec. 32, T. 22 N., R. 5 E., M. D., in the canyon of North Fork of Feather River, near the stream and the Western Pacific Railroad line. In 1929 the late W. S. McLean shipped a few hundred tons of limestone from this deposit, and this is the only recorded production from the immediate locality, although marble deposits have been known and briefly described previously. See *Big Bend marble.*

Mickey deposit is assessed to F. K. Mickey, general delivery, Chico. It is in sec. 31, T. 24 N., R. 3 E., M. D., at an elevation of 1500 feet and 16½ miles northeast of Chico by road. Many years ago a lime kiln was operated here and lime was hauled to Chico for local use. There has been no recent work. The deposit was not visited because of its distance from possible markets, but is believed to be small.

Mooretown Marble. A ledge of "white marble" has been mentioned 2 miles southeast of Mooretown. It has not been visited, as it is about 20 miles from the railroad. It is said to be 20 to 30 feet wide and 100 feet long in outcrop.

Parish limestone is assessed to Pacific Gas & Electric Company, 245 Market Street, San Francisco. It is in the E½ sec. 18, T. 12 N., R. 4 E., M. D., about half a mile east of the Pentz-Nelson Bar-Yankee Hill road. There is a small quarry and a short adit on this land which supplied limestone for a kiln operated 40 years ago. It is one of the deposits which has been investigated for possible use in making cement. Analyses made by Smith Emery & Co. and by W. C. Blasdale indicated from 95.6 to 98.47 percent $CaCO_3$, from 0.62 to 2 percent silica and less than 1 percent each of alumina, iron oxide, and magnesia. It may contain 250,000 tons to a depth of 100 feet if surface dimensions are maintained to that depth.

Poe (King) deposit is owned by El Dorado Limestone Company, Shingle Springs, California; J. H. Bell is general manager. It is in sec. 18, T. 22 N., R 5 E., near Poe, 4 miles south of Pulga and partly just above the tracks of the Western Pacific Railroad. It is a small but high-grade deposit and well located for cheap mining and loading on railroad cars. It was opened in 1929 and produced several hundred tons, but in 1930 was purchased by the present owner and has remained idle since.

Wilson limestone is assessed to Pacific Gas & Electric Company, 245 Market Street, San Francisco. It is in S½NE¼ sec. 18, T. 21 N., R. 4 E., M. D., and is another of the group of small deposits which were checked as possible sources of limestone for making Portland cement. Analyses indicate a high-calcium limestone with 1.27 to 1.70 percent SiO_2 and very low alumina, iron oxide, and magnesia content.

Calaveras County

Although the limestone resources of this county are immense, the only large development has been that of Calaveras Cement Company. The great Columbia marble belt, which extends for miles across Tuolumne County, is over 3 miles wide where it enters Calaveras County at the North Fork of Stanislaus River. It extends from there over an area of about 15 square miles. About a quarter of this was covered by flows of andesite tuff, latite, and rhyolite which mantled old gold-bearing gravel. The mining of the gravel exposed the old eroded limestone bedrock at Douglas Flat and Murphy, similar to that around Columbia. In elevation, the limestone extends from a little below the 1000-foot contour at the river to the 2000-foot contour near Douglas Flat, and 2200-foot contour at Murphy. So, while the conformation of the rocks on which it rests is unknown, the total volume must be stupendous. In general, it is similar in appearance and would probably prove similar in composition to the limestone and marble in the same belt in Tuolumne County. Some of it is highly magnesian, and careful examination and sampling would probably reveal the same wide variation from high-calcium limestone to dolomite in adjacent bands.

Attempts were made in the past to open marble quarries at places in this large deposit. This was during the years when Angels Camp, 5 miles west of the main marble belt, had railroad service over a branch of the Sierra Railroad from Sonora via Melones. This service was ended and the rails removed several years ago. The nearest railroad points now are at Kentucky House about 15 miles by road northwest of Vallecito, and Sonora, 15 miles south. There has been no activity at these marble quarries in the past 20 years. Other marble deposits in the vicinity of San Andreas and on Bear Mountain, have also remained idle.

In the western part of the county between Valley Spring and Paloma and within a short distance over good roads from the railroad at Valley Spring, there are several small limestone deposits which were worked to furnish flux for the Campo Seco copper smelter, but this has been idle about 20 years. Their favorable location might permit the use of some of this stone by consumers looking for small tonnage.

Calaveras Cement Company's plant is at Kentucky House and is served by a branch of the Southern Pacific Railroad from Valley Spring. The main office is at 315 Montgomery Street, San Francisco. The plant has been in operation since June 1926. It has been described in detail by the author (Logan 36, pp. 227, 232-233), and by Townsend (33). It is a wet-process plant and with the improvements and additions made during the past 2 years has a daily capacity of 7500 barrels. Starting with limestone deposits near Kentucky House, the company later opened a quarry near Old Gulch, northeast of Calaveritas. They also own limestone-bearing land

in sec. 1, T. 5 N., R. 12 E., and sec. 6, T. 5 N., R. 13 E., 6 to 7 miles east of Mokelumne Hill. In both localities there are clusters of limestone outcrops in the Carboniferous (Mississippian) rocks which have been exposed by erosion in the stream canyons. A private road was built to the limestone near Old Gulch and high-speed hauling of stone has been employed over it since 1935.

The recent additions to the plant include an Allis Chalmers kiln 11 feet 3 inches by 360 feet to supplement the two old 240-foot kilns, and the necessary crushers and mills for handling the increased tonnages of both stone and clinker. Diesel side-dump semi-trailer trucks with two dump-bodies each and a capacity of 35 tons are used for hauling limestone $5\frac{1}{2}$ miles from No. 4 quarry near Old Gulch.

Limestone is drilled with churn drills, holes are chambered and large tonnages broken down by simultaneous blasting. Large blocks of stone are reduced by block-hole blasting. A Bucyrus 120-B electric shovel is used for loading trucks.

About 400,000 barrels of this company's low-heat cement was used in the San Francisco-Oakland Bay Bridge. Eight kinds of cement are made, including a white portland cement. This company (and a few others) have used some of the light-colored high-alumina clay of the Ione district, Amador County, for making special types of cement.

Limestone Deposits

Cave City limestone deposit is 10 miles northeast from the railroad and cement plant at Kentucky House. It is the largest deposit in the western part of the county, comparing in size with the Volcano deposit in Amador County. Like the Volcano region it was once the scene of placer mining; there were some 1000 inhabitants in Cave City. The deposit is of Carboniferous (Mississippian) age.

The deposit is over 2 miles in length and extends over a vertical range of 500 or 600 feet between elevations of 1500 and 2100 feet. Crystal Cave in this limestone has been known since 1850, but because of its remoteness has not received the attention given to the caves near Murphy and Vallecito.

There is a very large tonnage of limestone in this deposit but its development may have to wait the exhaustion of smaller but more accessible deposits. A climb of over 1000 feet is involved in reaching it by present roads from Kentucky House.

Gale Ranch deposits, address Oscar Gale, Mountain Ranch, are in secs. 20 and 29, T. 5 N., R. 11 E., M. D. The small deposits reported on this ranch are 8 miles from Valley Spring and were not visited. From this ranch northwestward into Amador County there are numerous small bodies of limestone which lack roads and are rather remote from railroads.

Le Clerq Limestone. This deposit, 7 miles northeast of Valley Spring, and once productive, is now reported to be covered by the water of Pardee Dam.

Markwood Ranches are assessed to Mary E. Markwood and Charles R. Markwood, Valley Spring. There are some small bodies of limestone on these properties. The most accessible, in $N\frac{1}{2}N\frac{1}{2}$ sec. 32, T. 5 N., R. 11 E., M. D. shows an outcrop of possibly half an acre with no backs above the

surface. It is probably similar in quality to that on the adjoining McNamara property.

McNamara limestone is owned by Josephine McNamara and Mary E. Gallagher, Valley Spring. It is in sec. 32, T. 5 N., R. 11 E., M. D., $5\frac{1}{3}$ miles by good road northeast of Valley Spring.

This deposit is 1200 feet long, strikes north, and has a width of 150 to 210 feet with maximum backs of 70 feet. Three thousand tons of limestone was mined under contract from the south end of it, and smaller quantities from other parts, for use as flux in the Campo Seco copper smelter. No work has been done lately. Following is the report of analysis by Abbot A. Hanks, Inc., of a sample taken in November 1943:

	Percent
Insoluble	2.99
Ferric and aluminic oxides	1.21
Calcium carbonate	89.90
Magnesium carbonate	5.63
	99.73

Penn (Plaza) deposit is owned by Penn Mining Company. It is in sec. 32, T. 5 N., R. 11 E., M. D., 5 miles by good road from Valley Spring. The owners used this as a source of limestone for flux in their copper smelter at Campo Seco. No work has been done on the deposit in recent years. An open pit 200 feet long by 50 feet wide, with a maximum depth of 40 feet, was worked to the property line on the county road. The limestone does not outcrop south of the road and the deposit is about worked out to the floor of the pit with little room for further operation without sinking. The production was probably about 15,000 tons.

Watt and Field (Young) deposit is assessed to Hannah R. Watt and Albert Field, Valley Spring, and others. It is in N$\frac{1}{2}$ sec. 4, T. 4 N., R. 11 E., M. D. 5 miles by road northeast of Valley Spring but only 2 miles from the railroad running to the cement plant. A series of limestone outcrops, most of them small, extends for half a mile N. 25° W. The largest exposure is on the south end, and is 600 feet wide. It may be too siliceous, except for use in portland cement. There is also a siliceous outcrop 80 feet wide on the north end. Between the two there are numerous small outcrops from 6 to 60 feet wide, none conspicuous. It is possible that the deposit is continuous, but this could only be proven by trenching or drilling. In earlier days several lime kilns were operated on this land but most of the limestone burned must have been gathered from the surface, as there is little evidence of excavation. Backs of about 60 feet could be obtained on the north end and less to the south, before reaching the level of the small creeks draining the land.

The sample which gave the analysis quoted below was taken from 11 small outcrops from 6 to 60 feet wide, and represents the better-grade limestone. Analysis November 13, 1943, by Abbot A. Hanks, Inc.

	Percent
Insoluble	2.23
Ferric and aluminic oxides	1.29
Calcium carbonate	93.10
Magnesium carbonate	3.02
	99.64

Marble Deposits

Most of the limestone in the county has been changed to marble, and there is an immense amount of it available. As the principal body is the north portion of the large marble outcrops extending northward from Columbia, Tuolumne County, where there has been a large production of high-quality marble, there is no doubt that the marble in Calaveras County would be found to be of high quality also. The places mentioned below are only those where there has been some record of past activity. There are probably other possible quarry sites in the Murphy and Vallecito districts.

Angels marble quarry is in secs. 33 and 34, T. 3 N., R. 14 E., M. D., 3 miles southeast of Vallecito on the west side of the canyon of Stanislaus River. Forty to 50 years ago some work was done and two shipments of marble were reported. It is a fine-grained, nearly white marble with faint gray veining.

Bishop marble (Marble placer mine) is in secs. 17 and 18, T. 2 N., R. 13 E., M. D., 2 miles northeast of Melones on the west side of Stanislaus River. It is undeveloped.

Caldwell marble quarry is in sec. 35, T. 4 N., R. 11 E., M. D., 4 miles southeast of Valley Spring on Bear Mountain. It is a dark mottled marble. Apparently some work was done irregularly 50 years ago, and the stone is said to take a fine polish. There is no record of any sales.

Eagle marble quarry is in sec. 28, T. 3 N., R. 14 E., M. D., 1 mile southeast of Vallecito on a 160-acre homestead. Thirty years ago there was some equipment on this land, including an air-compressor, hoist, and derricks, and it was said that some shipments of marble had been made. About 1925, Eagle Marble and Lime Company did some work, but no production was recorded. The marble is nearly white with faint gray veining.

Hertzig marble quarry was in sec. 29, T. 4 N., R. 12 E., M. D., near the site of Calaveras Cement Company's plant, and probably on land now held by that company.

Treat marble quarry is in sec. 16, T. 4 N., R. 12 E., M. D., 1¼ miles east of San Andreas. The deposit is on a hillside and easily accessible. It is a very compact, finely crystalline white and mottled marble. It was used in erecting the Hall of Records at San Andreas.

A mile northwest along the strike of the Calaveras beds, there are 2 small bodies of marble on each side of Murray Creek, a short distance east of the Mokelumne Hill road. About 1½ miles farther northwest, 2 more small outcrops occur. None of these have been developed.

Walter C. Sundberg, Sonora, has recently used some yellow marble from an unnamed deposit near Vallecito to make terrazo at a small crushing plant operated at Chinese railroad station in Tuolumne County.

Colusa County

Although limestone is known to occur at several places in Colusa County, and some lime has been burned in years past for local use, no statistics of production are available. The eastern half of the county is

covered by the alluvium of Sacramento Valley, and the limestone deposits are mostly in the quicksilver mining districts adjacent to Sulphur Creek about 30 miles west of the railroad. Lime has been used in construction work at the mercury mines, in the treatment of soot for the recovery of mercury, and in retorting cinnabar concentrate. The following occurrences have been noted:

Elgin Quicksilver Mine. In the SE¼ sec. 13, T. 14 N., R. 6 W., and sec. 18, T. 14 N., R. 5 W., 4 miles northwest of Wilbur Springs post office by road and 30 miles east of Williams, the nearest railroad point, is an outcrop of hard white material inclosing fragments of shale, on the slope below the Judge Moore tunnel. This was analyzed by the U. S. Geological Survey (Waring, G. A. 15, p. 105) and found to consist ''mainly of calcium and magnesium carbonates with only small amounts of silica and water'' but is not dolomite.

Lambert Ranch in sec. 20, T. 16 N., R. 5 W., contains a deposit from which some lime was made many years ago.

Manzanita Mine. There is a deposit of crystalline limestone on the western part of the Manzanita property, in the NE¼ sec. 29, T. 14 N., R. 5 W. Years ago some of it was used locally, but nothing has been done there recently.

Onyx Marble. (Aragonite, California Onyx). Previous to 1888, some stone which has been variously described as aragonite and onxy marble was shipped to England from a narrow bed which outcrops near the head of a branch of Sulphur Creek (Irelan, W., Jr. 88, p. 159; Goodyear, W. A. 90, p. 156; Kunz, G. F. 05, p. 111). In 1888, a company called California Onyx Company had 48 acres ''at the head of Sulphur Creek.'' Goodyear (90, p. 156) described some aragonite which he found only in loose pieces about a mile west of Wilbur Springs (the name applied in earlier days to the present Elgin Mine Hot Springs). He called it ''handsome, the banding being wavy and extremely thin and delicate.'' Nothing has been done with it commercially in late years. In 1929, four claims were located for onyx marble 1 mile north of the north end of the Elgin mine, which would place these claims in the SE¼ sec. 12, T. 14 N., R. 6 W. The claim owner reported the deposit formed a capping about a foot thick, 20 feet wide, and 150 feet long. When polished, the marble is an attractive brown banded stone. Probably the reason this deposit, and other similar ones in California, have not been operated for any length of time is because they cannot furnish commercial quantities of good sized pieces.

Shell Deposits. Beds of shells, generally in limited quantity, have been mentioned by Goodyear (90, pp. 160 et seq.) and by Forstner (03, p. 42). The largest one is on the *Wide Awake* property, which is on the south side of Sulphur Creek, adjoining the Wilbur Springs resort property on the west.

Contra Costa County

The first lime made in California after the American occupation was burned in the spring of 1851 near Pacheco by a man named Shreeve, at what was called the Mt. Diablo quarries, but no definite record of lime production in the county was kept before 1903. Lime production con-

tinued until 1915, coming from the plant of Henry Cowell Lime Company 3 miles east of south of Concord. Spreckels Sugar Company produced limestone from deposits 5 miles from Concord for use in their sugar refinery and for sale to Selby Smelter until they sold out in 1915 to the Cowell interests, who had gone into the Portland cement business. The cement plant has been in operation ever since at Cowell on Rancho Monte del Diablo, about 5 miles by road south of east of Concord. In later years, most of the limestone produced in the county has been used in this plant, which has been closed down during 1946.

The deposits are of Recent travertine, occurring in a number of shallow beds, 20 feet or more thick, covered only by a thin bed of clay. They are along the Monte Diablo fault zone. The stone is mostly compact, brown, and faintly banded, but in places is bluish or white. Although not regarded originally as large, important, or particularly high grade, these deposits have continued to produce large quantities of stone that has proved satisfactory for cement making. The clay used in the plant occurs nearby.

The geology of only the western part of Contra Costa County has been systematically covered. Although the results of geologic work done in the Mount Diablo quadrangle for private clients have been published in part (Taff, J. A. 35; Clark, B. L. 35) these give scanty notice to limestone deposits.

In the part of the county covered by the Concord quadrangle and the northeast part of the San Francisco quadrangle, both included in the San Francisco Folio of the U. S. Geological Survey (Lawson, A. C. 14), a great deal of detailed field work was done by several classes of students in geology at the University of California. This resulted in probably much closer examination than would be expected in an area with few important mineral deposits. The results of this work, so far as limestone is concerned, were summarized in the following brief statements, quoted from the folio:

> "A few thin lentils of limestone occur in the Cretaceous rocks, but they have no commercial value. There are also many lentils of impure ferruginous and phosphatic limestone in the bituminous shales and cherts of the Monterey group."
>
> "In the Orinda and Siesta formations limestone lenses occur more or less persistently at several horizons, and similar beds of limestone are interstratified with the lavas of the Moraga formation. All these lenses are of lacustral formation and most of them are siliceous. The best that can be said of them as to their economic value is that some of them may prove to be of service for local use."

All of these are Pliocene formations. The Orinda is the most extensive, extending from the southeast corner of Concord quadrangle in a northwesterly direction to Giant and Sobrante. It has a surface width of 2 to 4 miles. No limestone has been separately mapped in this formation. In the freshwater Siesta beds at their contact with the volcanics of the Moraga, a few of the larger limestone deposits were shown. The largest of these is less than 1 mile north of Wilcox in sec. 15, T. 1 S., R. 3 W. It has been mapped as half a mile long by 500 feet or more in width.

Henry Cowell Lime & Cement Company. The cement plant is at Cowell, about 5 miles south of east from Concord and the travertine and clay used are quarried along the Mount Diablo fault nearby. Although the deposits of travertine on the part of Lime Ridge covered in the adjacent Concord quadrangle were not mentioned favorably in the San Fran-

cisco folio (Lawson, A. C. 14) the beds of this mineral worked by the Cowell interests have supported the cement plant for a long time.

An analysis of a sample of the Cowell travertine taken by E. C. Eckel indicated 95.7 percent $CaCO_3$, 1.4 percent silica, 0.92 percent alumina, and 0.76 percent magnesia. Several of the superficial deposits, 20 feet or more in thickness have been worked by electric shovel. The cement plant has a capacity of 4800 barrels a day. Operation of this plant was ended in 1946.

This travertine has been derived by springs from the calcareous sandstone of the Tejon (Eocene).

Mount Diablo lime marl deposit is on Lime Ridge about 5 miles northeast of Walnut Creek. From 1924-27 inclusive the Mount Diablo Lime Marl Company operated a plant there for grinding and screening the material which was sold for agricultural use. There has been no record of activity since.

El Dorado County

El Dorado County contains some of the largest high-calcium limestone deposits in northern California, located within a few miles of railroad, and will probably remain as it was in the past, one of the principal sources of such stone. In 1936 El Dorado County produced over half of all "industrial" limestone marketed in the state. In 1941, work at the largest producer, Mountain Quarries, was stopped, but announcement has just been made that the owners of another property will begin work at a deposit in the same district on the north side of the county this year. Operation of another deposit near Rattlesnake Bar, formerly worked by Auburn Chemical Lime Company, is also announced and both these will probably be well under way before publication of this report, giving four active properties. For many years prior to the exploitation of shell deposits in South San Francisco Bay, Mountain Quarries furnished 1000 tons or more of limestone a day which was shipped to a cement plant then operated at Cement, Solano County, but since closed. Thereafter, the quarry was a large seasonal producer of limestone for other industries.

The limestone deposits form part of the Carboniferous beds locally called the Calaveras formation. The differentiation of the Carboniferous has not been worked out in this region. The assignment to the Carboniferous was made on the basis of limited fossil evidence, as the limestone and the beds with which it is associated have undergone such intense dynamic metamorphism that little such evidence has survived. The limestones in western El Dorado are thoroughly crystallized as a result of the pressure, and stand usually as nearly vertical lenses with their longest dimension striking nearly north. There is often little evidence of the originally sedimentary rocks, such as slate, chert, and quartzite, to be expected normally with them. The prevailing wall rock in which the limestone is encased has long been known and mapped as amphibolite schist. It is believed that the layers of such rock containing the limestone should be called para-amphibolite schist, to indicate its probable derivation from sediments or from volcanic ash which either settled as dust from the air upon the ocean or was interbedded with the limestone by sedimentation. Otherwise, it is hard to explain the absence of evidence of contact metamorphism such as wollastonite, garnet, or other calcium silicates, or

sharply marked variations in crystal size and degree of silicification of the limestone (or marble) itself. Several or all such phenomena are to be observed in limestone in regions invaded by igneous rocks.

Auburn Lime Products Company. Fred Weybret of Salinas is president. Main office is at 486 California Street, San Francisco. John J. Taylor is secretary and general manager.

This is a new company formed to work a limestone deposit about a mile southeast of Rattlesnake Bar, which has previously been operated at intervals since the sixties by Holmes Lime Company, Farmer Lime Company, Newcastle Lime Company, and between 1930 and 1942 by Auburn Chemical Lime Company. The present company has installed a rotary kiln and crushing equipment and plans to be in operation soon (May 1946). Newcastle, 7 miles northwest, is the rail shipping point.

The deposit is a lens of high-calcium limestone standing nearly on edge in amphibolite schist, striking nearly north, and dipping steeply east. It is bluish gray to white, of medium to fine subhedral crystals. There are a few narrow streaks of schist in the limestone. The age of such deposits in the Sierra Nevada foothills has generally been considered Calaveras (Carboniferous, Mississippian) but the classification is based on meager fossil evidence found in only a few of the limestone beds, and most of the lens-shaped deposits, such as this one, have undergone enough metamorphism to destroy possible fossil forms. Some of the deposits may be Permian.

In earlier days lime was burned on the north part of the deposit near Alabaster Cave, where natural caverns in the limestone formed an attraction for sight-seers until many beautiful stalactites and stalagmites had been destroyed. The later work has been on the south. There two open cuts were run, one 300 feet long from the south and another 475 feet from the north. They have a maximum depth of 75 feet and a width of 25 to 50 feet so that a total of about 100,000 tons was removed. This part of the deposit stood above the kiln level, so the stone could be hand trammed to the top of the kilns. A large part of the lime was hydrated and sold for use in cyanide plants treating gold ores, to farmers for use in fruit-tree sprays and as a soil corrective. Some limestone was also ground and sold for glass making, as well as for agricultural purposes. A $CaCO_3$ content of 97 percent was claimed and analysis by the State Department of Agriculture showed 97.53 percent $CaCO_3$.

After the above was written, this company completed the installation of the plant, and operated until October 1946. During the above short period of activity, limestone was taken from the south quarry. Down holes were drilled with jackhammers, and after blasting, large blocks were broken by hand with sledges to one-man size. Stone was loaded into trucks by diesel tractor shovel and hauled to the plant. Part of the limestone was crushed and screened in a small plant containing a jaw crusher, hammer mill, ''Ripl-Flow'' and ''Hum-mer'' screens, which produced turkey grit, chicken grit, and limestone flour. Most of the stone went to a size 50 ''Kue-Ken'' crusher which broke it to kiln size.

Early in 1947 the owning company resumed operation of the lime kiln. Since then all limestone has been purchased from California Rock and Gravel Company near Cool, and hauled 10 miles by truck. This limestone is the minus 2-inch material left after preparation of coarser sizes. It is a dense, fine-grained, hard gray stone carrying 98 to 99

percent $CaCO_3$, and making excellent lime, most of which is shipped to steel plants. George L. Kelly, Auburn, is manager, and Ray Webber is plant superintendent.

The new rotary kiln is 4 by 60 feet and is equipped with a pre-heater in which limestone is heated to a temperature of about 1000 degrees Fahrenheit by waste heat from kiln. The stone is fed to pre-heater by bucket elevator and discharged from it to kiln by a plunger operated by eccentric with 1-inch throw. The kiln has a capacity of 27 tons of lime daily. It is fired with 15-degree gravity crude oil, heated to 160 to 180 degrees and supplied under 60-pound pressure. Burnt lime is discharged to a cooler section about 30 feet long. From there it is taken by bucket elevator to a two-deck vibrating screen which is housed on top of the storage silo. This silo is a new type supplied locally by Mark Lintz, San Francisco. It is 18 feet in diameter by 36 feet high, divided into four compartments by bulkheads and has space at the base for sacking machinery and scales. The capacity is 200 tons of lime. It is built of concrete staves containing $\frac{3}{8}$-inch reinforcing bars. The staves are keyed together laterally with wooden splines $1\frac{1}{4}$ inches square in cross section and bound with steel hoops, under which wooden battens cover the joints.

Besides the old quarries from which most of the limestone has been taken in the past, the company has acquired rights on the north, giving it a length of about 3000 feet along the strike including the Coles property.

The following analysis of limestone is of a sample taken by the writer over a width of 25 feet in the south pit; it was made by Abbot A. Hanks, Inc.

	Percent
Insoluble	0.32
Ferric and aluminic oxides	0.27
Calcium carbonate	98.94
Magnesium carbonate	0.38
	99.91

The following analysis of quicklime made in the new plant was furnished by the company:

	Percent
SiO_2	0.10
Al_2O_3	0.91
Fe_2O_3	0.07
CaO	94.64
MgO	0.49
S	0.004
P_2O_5	0.167
CO_2	0.42
Volatile	3.19
Total	99.991

Cowell Cave Valley Deposit. Owner of this deposit is Henry Cowell Lime and Cement Company, 2 Market Street, San Francisco. It is in secs. 6, 7, and 18, T. 12 N., R. 9 E., M.D., 5 to 6 miles by good road east of Auburn. The total land holdings on this deposit cover 947 acres and the deposit extends for about 2 miles in length with an exposed width of 200 to 400 feet. It includes one large lens and part of another $1\frac{1}{4}$ miles on this property, the northern portion of the latter having been worked on

an adjoining property for a part at least of every year from 1910 to 1942. It was mined in a large open pit up to the Cowell property line, and to a depth of 800 feet. This northerly lens was traversed by the Middle Fork of the American River and the canyon permitted operation to this depth by starting near the river level.

Aside from their exceptional size, these limestone deposits are typical of the series of roughly lens-shaped bodies found in the Calaveras (Carboniferous, Mississippian) meta-sediments of this section of the Sierra Nevada. The series of beds have been folded and compressed so that the lenses of limestone stand nearly on edge, and where exposed by erosion they have the character of frozen veins. So general and intense has been the metamorphism that the limestone is all crystallized, firm to tenacious in texture, and generally devoid of visible organic remains, except for the finely divided carbonaceous residue which gives it the prevalent blue-gray to nearly black color, which is subdued by weathering to a typical dove-gray shade. But it is remarkable that, in spite of the metamorphism, every one of these deposits was found to be a "stinkstein" (fetid limestone), giving a more or less pronounced odor on being hammered.

Cave Valley Lime Company quarried the limestone on both sides of the Auburn-Cool road and made lime in two kilns 40 to 50 years ago. The workings were shallow, as the limestone outcrops there do not stand much higher than the general ground level. The fullest development without recourse to hoisting would require entry from the south side of the river canyon and if the south lens proved to extend as deep as the north lens, the tonnage of limestone in it alone to a depth of 500 feet would be sufficient to justify a plant of any size.

The following analyses were of large samples taken by chipping good sized pieces at regular intervals, across the widths indicated:

Sample across 270 feet	*Percent*	*Sample across 400 feet*	*Percent*
Insoluble	0.22	Insoluble	1.02
Fe_2O_3 and Al_2O_3	0.25	Fe_2O_3 and Al_2O_3	0.29
$CaCO_3$	98.50	$CaCO_3$	98.14
$MgCO_3$	0.34	$MgCO_3$	0.45
	99.31		99.90

This property was leased to *California Rock and Gravel Company*, 1800 Hobart Building, San Francisco, in 1946 and at time of the author's visit in October 1946 was being worked for them under contract by E. B. Bishop. Several hundred tons of limestone was being shipped daily from Auburn.

A face 50 feet high by 300 feet long has been opened on the limestone in section 7 about a quarter of a mile north of the highway. Five wagon drills are operated 2 shifts, drilling 30-foot holes on 6-foot centers. These are shot with 60 percent Atlas dynamite, as the limestone is tough and hard. Large blocks of stone are blasted small enough to load with 1½- and 2½-cubic-yard power shovels into trucks, which deliver limestone to the 30- by 42-inch primary crusher, which is set to 7½ inches and operated by 100-horsepower motor. From this it passes by belt conveyor to a trommel with 6-inch square holes, and oversize goes to secondary crusher. Another

belt conveyor delivers all stone to a double-deck screen on top of the loading bins. This screen delivers two sizes, 2 inch by 4 inch and 4 inch by 6 inch to separate bins for loading into trucks which haul it to railroad cars at Auburn. The minus 2-inch material is carried by a belt conveyor to a stockpile. Bin capacity is 900 tons. Three portable air compressors are used, two drills requiring a 500-cubic-foot compressor. Electric power is supplied by Pacific Gas & Electric Company.

At present a 7-day week is worked and stone is being shipped to beet-sugar refineries, which require a large tonnage during their operating season, in autumn and winter. These refineries burn the limestone in vertical kilns, so demand a hard, fine-grained stone that will make good lump lime. This deposit, as shown in analyses of samples taken by the writer, is a very high-grade, high-calcium limestone, and according to Boyd Oliver, vice president of California Rock and Gravel Company, recent analyses have indicated over 99 percent $CaCO_3$, with less than 0.025 percent iron.

California Rock and Gravel Company took over operation of the property, doing considerable advance prospecting during the early part of 1947, followed by heavy production throughout the dry season.

Diamond Springs Lime Company. Homer P. Brown is general manager of the company, whose main office is at Diamond Springs. This modern lime plant was established in 1927 at Diamond Springs on the Placerville branch of the Southern Pacific Railroad. They do a general lime business supplying many grades of lime and lime hydrate, but during the war the larger part of the output was of high-calcium lime made from limestone produced at the mine of El Dorado Limestone Company near Shingle Springs. This was used principally by steel mills. They also operate a deposit of magnesian limestone in the SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 28, T. 10 N., R. 11 E., from which the stone is sent to the plant over an aerial tramway 3 miles long, with 149 buckets of 800-pound capacity, capable of delivering about 250 tons of rock to the plant in 8 hours. This deposit has been drilled to a depth of 600 feet. A Link-Belt electric shovel is used for stripping, digging, and loading limestone. A face up to 36 feet high is broken by drilling vertical holes with jackhammers using steel as much as 36 feet long, and blasting with 40 percent Trojan bag powder. One pound of powder is said to break 4$\frac{1}{2}$ tons of rock. The holes are spaced 10 feet apart in two staggered rows. When the height of face exceeds 36 feet, horizontal holes are also drilled near the bottom. Limestone is loaded by electric shovel into trucks which deliver to the primary crusher. From this the stone goes by belt conveyor to the bins serving the aerial tramway.

The flow sheet and tabular analysis included herewith were first published in *Pit and Quarry,* April 6, 1932; minor changes have been made for publication herein.

The two Vulcan rotary kilns, each 8 by 125 feet, are driven at speeds of from $\frac{1}{6}$ r.p.m. to $\frac{1}{2}$ r.p.m. by 25-horsepower electric motors. They are inclined half an inch in 1 foot and have an average capacity of 3$\frac{1}{4}$ tons an hour or 78 tons of lime a day each. Kiln temperature is about 1300° F. at the feed end and from 1800° to 2200° F. at the firing end. Fuel oil feed is controlled by valves with micrometer adjustment. Oil is fed at 225 pounds pressure and 280° F. Electric power at 60,000 volts comes over two lines to a special automatic sub-station adjoining the plant. Here

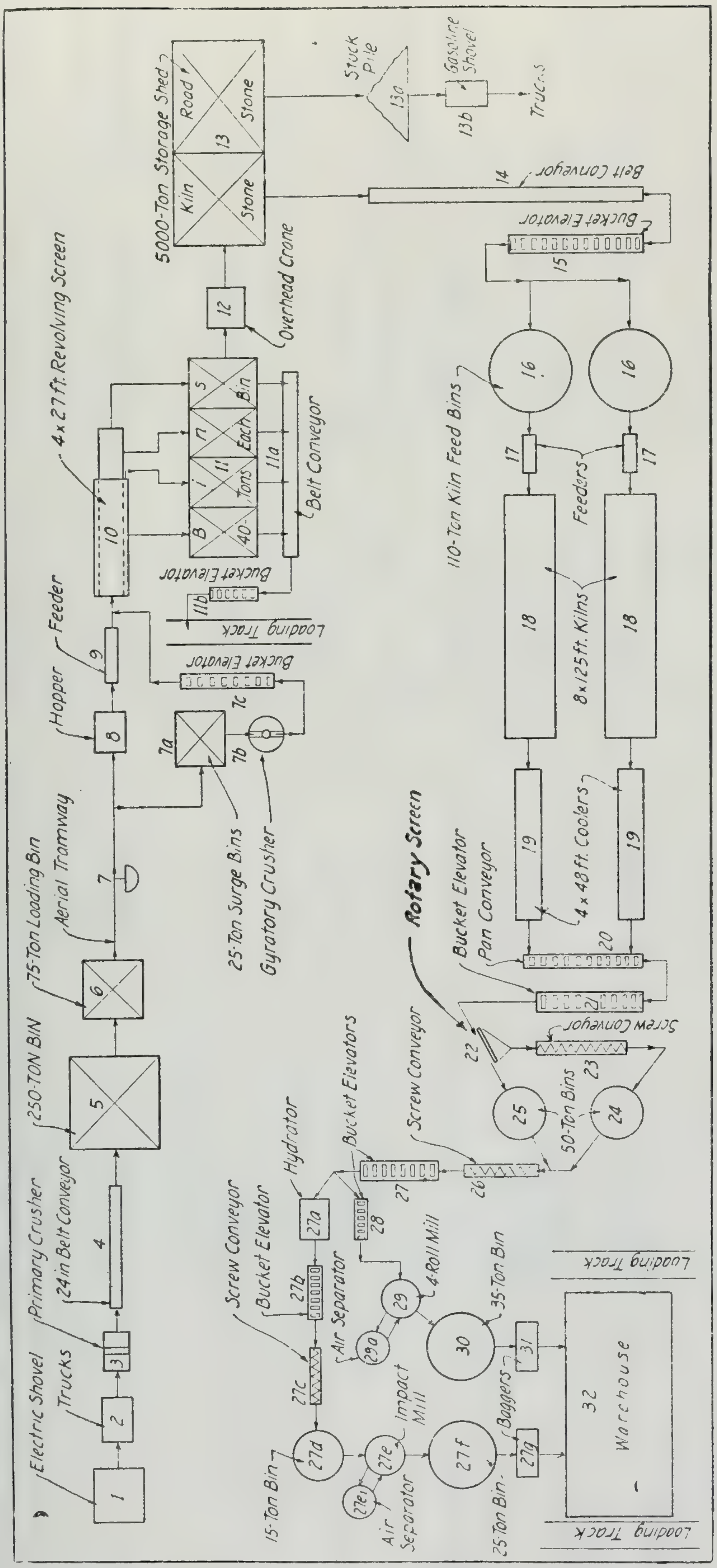


FIGURE 2. Flow sheet, Diamond Springs Lime Company plant, El Dorado County. *Reprinted from State Mineralogist's Report 34, p. 275, 1938.*

Tabular analysis of the operations and equipment of Diamond Springs Lime Co. plant at Diamond Springs, California

(The key numbers refer to the equipment shown on the accompanying flow-sheet)

Operation	Key	Equipment	Make	Model No., size, capacity or type	Power source	Power transmission
Raw-material recovery and transportation	1	Shovel	Link-Belt	$1\frac{1}{4}$-cu. yd. electric	60-hp. G.E.	Link-Belt silent-chain
	2	Trucks (2)	International	5-ton		
Primary crushing	3	Primary crusher	Allis-Chalmers	40-in. by 42-in. jaw	150-hp. G. E. slip-ring	Belt
	4	Belt-conveyor	Stearns	24-in. by 180-ft.	15-hp. G. E.	Belt
	5	Bin		250-ton		
	6	Loading bin		75-ton		
Transportation	7	Aerial tramway (Optional to 7a)	Am. Steel & Wire Co.	50-ton per hr.	40-hp. Westinghouse induction	Belt
	8	Hopper				
	9	Feeder	Link-Belt	Reciprocating type	5-hp. Westinghouse	Link-Belt silent-chain
Screening and storage	10	Revolving screen	Link-Belt	4-ft. by 27-ft.	15-hp. Westinghouse	Link-Belt silent-chain
	11	Bins (4) (Optional to car-loading 11a)		40-ton each		
Recrushing	7a	Surge-bin		25-ton		
	7b	Reduction crusher	Telsmith	8-in. gyratory	50-hp. Westinghouse	Belt
	7c	Bucket-elevator (To screening and storage 10)	Link-Belt			
Car-loading	11a	Belt-conveyor	Link-Belt	36-in. by 250-ft.	10-hp. Westinghouse	Link-Belt silent-chain
	11b	Bucket-elevator	Link-Belt			
Storage	12	Overhead crane	Judson Pacific Co.	$1\frac{1}{2}$-cu. yd.	2 50-hp., 1 15-hp., 1 5-hp.	Gears
	13	Open storage (Optional to stock-piling 13a)		5,000-ton		
Stock-piling	13a	Stock-piles				
	13b	Shovel	Northwest	$\frac{3}{4}$-cu. yd. gasoline		

Reclaiming	14	Belt-conveyor	Link-Belt	24-in. by 40-ft.		
	15	Bucket-elevator	Link-Belt	67-ft.	10-hp.	Link-Belt silent-chain
	16	Kiln-feed bins (2)	Link-Belt	110-ton circular		
	17	Feeders (2)	Link-Belt	Belt-type	Kiln drive	Chain and reeves variable speed transmission
Calcining	18	Kilns (2)	Vulcan	8-ft. by 125-ft.	25-hp. variable-speed	Link-Belt reducer and gears
	19	Coolers (2)	Vulcan	4-ft. by 48-ft.	15-hp. Westinghouse	Belt and gear
	20	Pan-conveyor	Link-Belt		5-hp. Westinghouse	Chain and gear reducer
	21	Bucket-elevator (Optional to quicklime screening and storage 23)	Link-Belt	60-ft.	7½-hp. Westinghouse	Link-Belt silent-chain
Quicklime screening and storage	22	Rotary screen (Oversize to 25, throughs to 23)	Link-Belt	3-ft. by 6-ft. single-deck	2-hp. Westinghouse	Belt
	23	Screw-conveyor	Link-Belt		5-hp. Westinghouse	Link-Belt reducer and silent-chain
	24	Bin	Link-Belt	50-ton capacity		
	25	Bin	Link-Belt	50-ton capacity		
	26	Screw-conveyor	Link-Belt			
	27	Bucket-elevator (Optional to hydrating 27a)	Link-Belt			
	28	Bucket-elevator	Link-Belt	40-ft.	5-hp. Westinghouse	Link-Belt silent-chain
Quicklime pulverizing and packing	29	4-roll mill	Raymond	4-roller	50-hp. Westinghouse	Belt
	29a	Air-separator	Raymond	No. 11 Exhauster	40-hp. Westinghouse	Belt
	30	Bin	Link-Belt	35-ton capacity		Belt
	31	Bagger (To storage for shipment 32)	Valve Bag Co.	4-bag	7½-hp. Westinghouse	
Hydrating	27a	Hydrator	McGann-Schulthess	6-t.p.h. capacity	15-hp. G. E.	Famous worm reducer and gear
	27b	Bucket-elevator	Link-Belt	40-ft.	7½-hp. Westinghouse	
	27c	Screw-conveyor	Link-Belt			
	27d	Bin	Link-Belt	15-ton capacity		
Hydrated-lime grinding and packing	27c	Impact mill	Raymond		20-hp. Westinghouse	
	27e	Air-separator	Raymond	No. 12 Exhauster	50-hp. Westinghouse	Direct-connected
	27f	Bin	Link-Belt	25-ton capacity		
	27g	Bagger (To storage for shipment 32)	Valve Bag Co.	4-bag	7½-hp. Westinghouse	Belt
Storage for shipment	32	Warehouse		50-ft. by 90-ft.		

it is stepped down to 11,000 volts then to 440 volts for plant and quarry use. Fuel oil and high-calcium limestone are brought in by rail.

Several grades of quicklime and lime hydrate are made. During the war about two-thirds of the chemical lime produced went to steel plants. Other important uses are in insecticides, water purification, paper and strawboard manufacture, and when gold quartz mining is active, it is used in the cyanide process. This lime is made from high-calcium limestone. The sales of chemical lime and chemical hydrate for agricultural use are relatively small.

Building lime and building hydrate are made from the magnesian limestone. About 3 tons of quicklime is sold to every ton of hydrate for this use.

The following analyses have been kindly furnished by Mr. A. W. Wilson, chemist at the plant.

	Diamond Springs limestone			*El Dorado Limestone Company's limestone*	
Acid insol.	1	2	3		
Incl. SiO_2	0.70%	0.43%	0.12%	0.41%	0.21%
Fe_2O_3 and Al_2O_3	0.65	0.51	0.14	0.36	0.21
$CaCO_3$	87.64	87.98	90.15	98.36	97.51
$MgCO_3$	11.01	11.08	9.55	0.87	1.59
	Chemical lime			*Building lime*	
Acid insol.	2.14%	0.26%	0.62%	0.52%	1.08%
R_2O_3	0.45	0.57	0.80	0.49	1.14
CaO	96.98	98.02	96.19	87.33	89.50
MgO	0.58	0.83	0.97	11.56	7.58
	Chemical hydrate			*Building hydrate*	
Acid insol.	0.34%	0.51%		0.54%	1.03%
R_2O_3	0.41	0.44		0.88	1.16
CaO	74.24	74.77		67.35	66.13
MgO	0.85	0.76		5.44	8.84
Ignition loss	24.15	22.62		23.65	22.81
Screen analysis (thru 200-mesh)	97.5%	95.1%		97.2%	91.9%

El Dorado Limestone Company, J. H. Bell, president, has 465 acres $4\frac{1}{2}$ miles by road southwest of Shingle Springs where limestone mining has been going on for 31 years. In earlier days, stone from the deposit was used to make lime for building purposes. *El Dorado Lime and Minerals Company* was the immediate predecessor of the present company, and their operations have been described by the author in a previous publication (Logan, C. A. 27, pp. 441-442). The present company was formed in 1931. J. H. Bell, general manager, has been in charge of operations for many years for this and the preceding companies. The company has a right-of-way with 1.9 miles of standard-gauge spur track connecting with the Placerville branch of the Southern Pacific Railroad.

The deposit occurs in a series of lenses of white, high-quality limestone dipping 85° E. in a belt of Calaveras (Carboniferous) rocks from a quarter to half a mile wide. The lenses are separated by strips of the country rock and in places small dikes cut across the limestone. For many years two lenses have been mined by shrinkage stoping and by using benches or slicing and underhand stoping. Drifts 20 feet wide by $8\frac{1}{2}$ feet high have been run. Widths worked have ranged generally from 20 to 70 feet. The object has been to make as much lump rock as

possible. Coarse rock is drilled and blasted in the stopes and is broken again by hand with sledges on the grizzlys over the loading pockets at the shaft. For blasting, 25 percent dynamite is used.

The mine is worked through a three-compartment vertical shaft 700 feet deep and the deposit has been proved for 1800 feet on the strike. The shaft is concrete-lined to the first level at 150 feet. Since the last report (Logan, C. A., 27) a new steel headframe 100 feet high and a 160-ton ore bin have been erected, and a new 3-ton double-drum hoist has been installed.

From the headframe, rock passes almost entirely by gravity through a Ku-Ken crusher, over vibrating screens and through trommels to separate the different sized products. During the process, coarse rock is washed and hand sorted on conveyor belts to remove pieces showing adhering schist or dike rock. The final product is a clean, white to translucent high-calcium limestone of such uniform quality that Mr. Bell states they "practically guarantee 98 percent $CaCO_3$". During the war, most of the output was shipped in railroad cars to the plant of Diamond Springs Lime Company where it was burned in two rotary kilns and shipped to steel mills. Other important uses are for paint, sugar- and glass-making. Sixty-seven carloads shipped to one user are stated to have averaged 97.65 percent $CaCO_3$ and 0.24 percent SiO_2.

The following analyses were furnished by J. H. Bell, who stated they were made by Abbot A. Hanks, Inc., San Francisco:

	Percent	*Percent*	*Percent*
SiO_2	0.60	0.60	0.72
R_2O_3 (Al,Fe oxides)	0.38	0.26	0.24
$CaCO_3$	98.4	97.93	98.38
$MgCO_3$	0.62	1.19	0.65

This deposit did not outcrop conspicuously and was not mapped on the geologic folio for that district. It is an example of several in the region that were eroded nearly or quite to the old peneplain level and have been partly covered by soil, so that the outcrops of limestone now visible do not give an accurate idea of the possible extent of the deposits.

Indian Diggings Marble Deposit. This deposit is in sec. 18, T. 8 N., R. 13 E., about 25 miles southeast of Placerville and has not been developed because of its remoteness from railroad. About a mile southwest of it, at Marble Spring, is another deposit. Both are good-sized.

Four miles northwest of Indian Diggings, and extending a mile and a half northeast across the canyon of Middle Fork of Cosumnes River from Slug Gulch to Rocky Bar, there is a large deposit of limestone. This is in part associated with copper ore at the Cosumnes copper mine. The association of limestone, copper ores, and magnetite is also found at other copper mines in the county. In such cases, the calcite has been re-crystallized into coarse crystals during the process of mineralization accompanying and following granitic intrusion. There has been no commercial utilization of such deposits.

Marble Valley Limestone (Henry Cowell Lime & Cement Company, 2 Market Street, San Francisco). Formerly these deposits were called the Schwalin marble quarry (in S½ sec. 8, T. 9 N., R. 9 E.,) and Marble Valley quarry (in N½ sec. 17, T. 9 N., R. 9 E.). Over 2500 acres of land surrounding these workings is assessed to the company.

Blue-gray to white limestone (marble) outcrops at intervals for over 2700 feet from the Schwalin pit southward to the south end of the Marble Valley quarry. At the north end the deposit is in and alongside of Marble Creek and the outcrop has been eroded down to the level of the surrounding land. The old pit from which stone was taken is 145 feet wide and not over 10 feet deep, as there was no provision for drainage. Though called a marble quarry, there is no evidence of any blocks of stone having been removed, and superficially it does not look as if such blocks could be had. The limestone was evidently burned in an old-style kiln nearby.

At the south end (sec. 17) there is an open quarry 180 feet wide by 300 feet long which has been worked to a depth of 20 to 25 feet. This is about the limit for which natural drainage is available. The north face is 120 feet wide, and shows good limestone; the west wall is not yet exposed.

The following is the analysis of a sample obtained by mixing samples cut across the width of deposit in both quarries mentioned above. Analysis was made by Abbot A. Hanks, Inc.

	Percent
Insoluble	0.43
Ferric oxide and aluminic oxide	0.42
Calcium carbonate	98.80
Magnesium carbonate	0.30
	99.95

These quarries are 3½ miles north of Cothrin on the Placerville branch of the Southern Pacific Railroad. Formerly the lime was hauled to that station for shipment.

Mountain Quarries (Pacific Portland Cement Company, 417 Montgomery Street, San Francisco). This large quarry in sec. 6, T. 12 N., R. 9 E., on the south slope of the canyon of American River, was for many years a main source of supply of limestone for making cement and for use in the sugar and steel industries. Production started in 1910 and continued through 1940. The crude limestone was hauled out over the company's own railroad 7 miles long connecting with the Southern Pacific a mile west of Auburn. Late in 1942, the rails on this line and most of the machinery at the quarry, as well as the locomotives used for hauling stone, were removed and sold, and all work ceased.

This was the largest limestone quarry in northern California and has been frequently described. The deposit is a large lens of gray limestone of which a substantial part has been eroded by Middle Fork of American River in forming its canyon. If the 1500-foot contour is taken as the approximate present level of the Cretaceous peneplain in that region, the river has cut a broad V-shaped valley nearly at a right angle to the schistosity of the amphibolite schist in which the limestone lies, to a depth of about 800 feet below the dissected peneplain, of which remnants have remained under coverings of auriferous gravel on hills in the region. Cutting of the canyon was apparently not at a uniform rate, and was faster in the lower, modern section. The limestone outcrops over the entire vertical range and has been found by diamond drilling to extend still deeper.

The quarry was opened near the river level and the upper bench was carried to the property line on the south. The photographs show the

character of the deposit. The dike seen in the picture of the upper workings near the south line is of augite porphyrite.

This body of limestone extends across the river but the part in Placer County is small. It appears there as a rather dark-gray stone, which is medium grained and tough and is a very high-grade high-calcium limestone.

Dolomite

Larkin Mine. For many years this old gold mine in sec. 29, T. 10 N., R. 11 E., 1 mile east of Diamond Springs, has been listed as having a ''large vein of dolomite''. (See Eakle, A. S. 23, p. 130, and Pabst, A. 38, p. 146; in both of these the name is mis-spelt ''Laskin''). This vein is 42 feet wide at the surface where it crosses the county road. It forms a part of the Mother Lode vein system here and in several other properties where serpentine is nearby. In this case, and in similar occurrences so far as have been observed, the dolomite is too impure to be commercially valuable (except where found to be a gold ore). It shows a rusty color on the outcrops due to oxidation of the pyrite it contains. In this case it also shows considerable talc and silica, and these impurities are quite generally present where the dolomite vein occurs.

Fresno County

Limestone occurs in a variety of forms in this county and is widely distributed. Marl deposits have been found in the younger formations both on the east side of the San Joaquin Valley and on the Coast Range side. Hard limestone and marble deposits are quite numerous in the eastern foothills and in the higher parts of the Sierra Nevada. South and southeast of Fresno much of the valley land is underlain at a depth of 3 feet or more by ''white hardpan'' in which the cementing material is calcium carbonate and magnesium carbonate. These carbonates were derived from the soil above. Marl occurs in the Mount Campbell district and the adobe soil over an area of several thousand acres surrounding Mount Campbell is mostly underlain by a light-colored marly material which is generally 6 feet or more below the surface, but in places is found at a depth of only 1 foot. Much of this marl has been sold.

In early days there was some production of lime in the county, as evidenced by the record of shipment of \$20,000 worth from Fresno in 1880. The source from which it came was not given, but it was probably from deposits near Dunlap and Alcalde, where kilns were still in operation in the late eighties. From 1931-39, marl was produced from deposits near Reedley and Minkler. During the present year the production of crushed limestone for poultry grits, stock feed, and foundry use has begun at a deposit a few miles north of Watts Valley. Except for the above, there has been no recent production of lime or limestone in the county.

Many occurrences of scheelite were found in Fresno County during the last war, along the contacts of granodiorite and metamorphosed limestone. These are listed herein to make the record of limestone deposits as complete as possible although some are too small, too far from railroads, or too impure because of metamorphism to be valuable as sources of limestone. Most of the limestone in this part of the Sierra Nevada has been changed to marble, and is in roof pendants which are remnants of much larger areas of pre-Cretaceous sedimentary rocks. The largest

area of such rocks extends from Friant on San Joaquin River east and southeast to Dunlap, a distance of about 36 miles.

Big Creek marble deposit (see *San Joaquin marble* and *Ellison Bros.*).

Coral Reef Lime Products Company produced marl for 6 years, 1931-36 inclusive, from a deposit in the Minkler district 25 miles east of Fresno near the Squaw Valley road and close to the Atchison, Topeka & Santa Fe Railway branch line. F. M. Secrest, principal owner of the land on which the deposit was found, claimed that 125 acres was underlain by marl 4 or more feet thick.

The marl was reached by stripping the soil overburden which varied from 6 inches to 3 feet in thickness. The upper part of the marl was then broken with a plow and mined with a scraper drawn by a tractor which delivered it to a grizzly over a loading bin from which trucks were loaded. When a ground product was desired, the marl was dumped on a belt conveyor, passed to a mill with a capacity of 100 tons daily through 40-mesh screen, and taken by another belt conveyor to a storage and loading bin. Ten men were employed.

Of nine partial analyses of the product made by the State Department of Agriculture, the lowest showed 38.2 percent $CaCO_3$ equivalent and the highest 55.9 percent, the average being 45.72 percent.

Drake Lime Company produced marl near Minkler in 1932, 1934, and 1936. H. E. Drake was manager. Ten partial analyses of the marl were made by the State Department of Agriculture, showing a variation from a minimum of 34.8 to a maximum of 59 percent $CaCO_3$ equivalent, with an average content of 46.31 percent.

Dunlap Deposits. In the eighties, a good grade of lime was made near Dunlap in the northern part of T. 14 S., R. 26 E. Two deposits supported three lime kilns which used oak wood cut nearby for fuel (Irelan, Wm. Jr. 88, p. 208). Two of the kilns had a daily capacity of 100 barrels of lime each. The distance from railroad (over 20 miles) probably caused cessation of work. The limestone is pre-Cretaceous, interbedded with slate and mica schist in roof pendants on granitic rock.

Ellison Brothers marble claims on Big Creek near the San Joaquin marble deposits, have not been developed.

Kings River deposits are in T. 12 S., R. 26, 27 E., on the north side of Kings River. Large limestone deposits have been known there for over 50 years. They have remained idle in late years as they are in mountainous country 25 miles or more northeast of Piedra, the nearest railroad point.

Montford marl deposit is on 40 acres in sec. 24, T. 21 S., R. 14 E., about a mile from Alcalde and 2 miles from Le Roy on the railroad. In the eighties lime was made nearby from a "vein" of limestone 12 feet wide which extends across 40 acres. This limestone contains a small amount of bituminous matter.

Mount Campbell Lime Company, Dinuba, produced marl from near Reedley from 1937-39. Two partial analyses made by the State Department of Agriculture indicated 46.5 and 47.6 percent $CaCO_3$ equivalent.

Sampson's Flat is north of Dunlap and on the south side of Kings River. A heavy ledge of blue limestone is reported there, but so far as known has not been developed.

San Joaquin marble deposit is in sec. 36, T. 8 S., R. 24 E., on Big Creek. The San Joaquin & Eastern Railroad crosses the section within less than a mile of the deposit and 500 feet above it, and a road connects with the Huntington Lake highway 2 miles distant. There is also an electric power house in the northwest quarter of section 36. A. Emory Wishon et al. at one time owned 125 acres on which the deposit occurs.

White, blue, and black marble of good quality is reported in a lens-shaped deposit lying mostly on the south side of the creek. It is said to extend probably for half a mile in length and to be 200 feet wide.

Twin Lakes deposit is in secs. 29, 30 T. 7 S., R. 26 E. (approx.)

This is a deposit of pre-Cretaceous crystalline limestone changed to marble and containing several smaller bodies of calc-silicate hornfels. It has been studied in detail by C. W. Chesterman (42). It is in the high Sierra Nevada, 3 miles north of the east end of Huntington Lake, at an elevation of 8500 to 8800 feet. As mapped, this limestone pendant is over 10,000 feet long and from 1250 to 3000 feet wide. Chesterman's article is interesting and valuable as a study particularly of the contact-metamorphic rocks formed where the Sierra Nevada batholith intruded a region deeply covered by older sediments, of which the original upper portions have been removed by erosion, including glaciation. He describes three kinds of marble for two of which partial analyses are given.

Calcite marble is most common and varies from gray banded to statuary white and skyblue. Its specific gravity is 2.69 and partial analysis was given as:

	Percent
CaO	47.42
MgO	5.92
Insoluble	1.20

The dolomitic marble, usually white, gave the following partial analysis:

	Percent
CaO	33.54
MgO	27.83
Insoluble	1.43

Some practically pure dolomite was mentioned as occurring with this.

Brucite marble, "characterized by the occurrence of small globular or spheroidal masses of brucite ($MgO. H_2O$)" occurs in limited quantity. Chesterman explains its occurrence as due to the hydration of periclase marble which he thinks was formed in the early period of contact metamorphism.

The examination of the region in 1942 was made with particular reference to scheelite, which occurs there in small quantities and no work was done on the marble, so far as known.

Webb & Mingus calcite prospect is in sec. 12, T. 20 S., R. 13 E., 10 miles northwest of Coalinga on Sherman Peak. No production has been reported.

Metamorphic Limestone with Scheelite

The following properties were investigated or prospected during the last war for scheelite and were listed by O. P. Jenkins (42, pp. 314-316). Marble and calc-silicate rocks may be expected with or near such scheelite deposits, but inspection of a county map will show that many of them are too far from railroads to be commercially valuable for limestone. Only one, the Red Bud, is being worked for limestone.

Benson Bros., sec. 18, T. 11 S., R. 25 E.
Big Oak, sec. 6, T. 11 S., R. 23 E.
Dixie Queen, sec. 3, T. 14 S., R. 26 E.
Emerald Peak, sec. 3, T. 9 S., R. 29 E.
Garnet Dike, sec. 22, T. 12 S., R. 27 E.
Houghton Bros., secs. 3, 4, T. 12 S., R. 26 E.
Humphreys, sec. 1, T. 11 S., R. 23 E.
Jack Pot, sec. 15, T. 11 S., R. 24 E.
Kings River, sec. 22, T. 12 S., R. 27 E.
Kings River South Fork, secs. 6, 11, T. 13 S., R. 29 E.
Mud Lakes, sec. 36, T. 9 S., R. 26 E., sec. 30, T. 9 S., R. 27 E.
McBride, sec. 11, T. 12 S., R. 26 E.
Qualls, sec. 14, T. 9 S., R. 26 E.
Red Bud, sec. 15, T. 11 S., R. 24 E.
Reiss, sec. 7, T. 11 S., R. 25 E.
Sadler, sec. 19, T. 9 S., R. 27 E., sec. 19, T. 10 S., R. 26 E.
Spanish Peak, sec. 14, 15, T. 11 S., R. 24 E.
Terrill, sec. 16, 17, T. 12 S., R. 25 E.
Three Buddies, sec. 1, T. 11 S., R. 23 E.
Tungstore (Dinkey Creek), sec. 21, T. 10 S., R. 26 E.
We Hope, sec. 22, T. 10 S., R. 26 E.

Red Bud Mine. Al Feuerstein is lessee, 3863 Kerckhoff Avenue, Fresno. The production of limestone has recently been started at this property which is about 5 miles southeast of Tollhouse and 40 miles by road from Fresno. Six sizes of poultry grits, and a seventh size for foundries are being made. Stone crushed too fine for grits is sold for use in stock food.

The following analysis has been furnished by Feuerstein:

	Percent
$CaCO_3$	97.68
$MgCO_3$	1.37
SiO_2	0.55
Fe and Al oxides	0.35

Glenn County

The populous, eastern one-third of Glenn County lies in the Sacramento Valley and consists of agricultural land in which no mineral deposits except sand and gravel have been found. The westerly two-thirds, rising gradually into the Coast Range, is occupied in succession, east to west, by Pliocene and Cretaceous sediments and by the Jurassic complex, partly sedimentary and partly metamorphic, including a good deal of serpentine. Several of these beds are known to carry limestone or marl in other parts of the state and a few small deposits in Glenn County have been mentioned in former reports, but there is no record of production from them. The principal mineral products have been sand and gravel from Stony Creek near Orland, and a few thousand tons of chromite from the serpentine in the Coast Ranges.

The few deposits of marble mentioned in past reports are in the southwestern part of the county and 18 to 20 miles from the nearest railroad points, Fruto or Riz.

Brown Deposit. From the description in Bulletin 38 (Aubury, L. E. 06, p. 99) this deposit is serpentine, which might be found suitable for use as marble, although not known to have been prospected or worked at all. It is reported to be in the "northwest corner of T. 18 N., R. 6 W." which would place it 2 to 3 miles from a good road, and northwest of Rockville.

Daniels deposit was reported in Bulletin 38 (Aubury, L. E. 06, p. 99) to be a ledge of white marble traceable for about a mile north and south along the east side of Stony Creek in sec. 21, T. 18 N., R. 6 W.

Nye deposit of onyx marble is reported to be on the Nye Ranch, in secs. 1 and 12, T. 18 N., R. 8 W., on the west side of Mount St. John near the Lake County line.

Humboldt County

Franciscan rocks are known to extend northwest across Humboldt County and are flanked by younger formations on both sides, but the geology has not been mapped in detail. Gold from beach placers and from placer mines in the Klamath River drainage in the northeastern corner of the county, and miscellaneous stone, have been the principal mineral products. Much of the county is rough and timber-covered. Production of redwood lumber and diversified farming have been the most important industries.

There are numerous relatively small deposits of limestone, and there was a limited production for local use in early days, but no recorded output has been shown since the compilation of statistics began in 1880, although there has been some production for agricultural use. Larger deposits on which no development has been reported, occur in the eastern and southeastern parts of the county. The Northwestern Pacific Railroad enters the southeast corner of this county, following the canyon of Eel River and is the only rail outlet. The town of Eureka has steamer service.

The population of the county was less than 50,000 according to the 1940 census. Eureka, the county seat, with more than one third of the population of the county, is the principal city of northwestern California. The limestone resources are ample for any local requirements likely to arise, but at present there is no operating lime kiln in the coast counties north of San Francisco Bay. As rainfall is rather heavy in the western part of the county and dairying is an important industry there should eventually be a local demand for limestone on the land where alfalfa and such crops are grown.

The following notes have been abstracted from past reports of the Division of Mines (Averill, C. V. 41, pp. 516-518; Lowell, F. L. 16, pp. 393-394).

Hackett deposit is in sec. 10 or 16, T. 1 N., R. 1 W., 4 miles southwest of Rio Dell on the west Fork of Howe Creek in steep country 2 miles from a road. An outcrop 20 feet wide by 30 feet high is exposed on the bank of the creek, and some large boulders were seen, but no work had

been done, so the amount of limestone concealed by the soil covering is unknown. No analysis is available. This deposit is about 5 miles from the railroad.

Jacoby Creek deposit is about 3 miles southeast of Bayside by road, of which the last mile was in poor shape in 1941. It has been known for many years and lime was formerly burned in an old kiln long since out of commission. An outcrop of limestone 20 by 50 by 15 feet is reported, on the side of the canyon of Jacoby Creek where a quarry could be opened.

This limestone was tested for possible use in portland cement over 30 years ago, with satisfactory results, but there has been no further development. The following is analysis of portland cement made from this stone by Smith, Emery & Company (Lowell, F. L. 16, p. 393):

	Percent
Silica	21.37
Aluminum oxide	6.49
Ferric oxide	2.93
Calcium oxide	62.22
Magnesium oxide	1.23
Sulphur trioxide	1.60

Johnston deposit is in secs. 4 and 9, T. 2 S., R. 1 W., H., 8 miles by steep road from Petrolia and over 30 miles from the railroad. Small outcrops, the largest reported to contain 20 to 25 tons, occur at intervals for 2 miles in a northwesterly direction. They are probably part of the Franciscan formation.

McClellan deposit is in sec. 5, T. 1 N., R. 1 W., H. 5 miles southwest of Weymouth Inn by steep road. It is a deposit of calcareous tufa, covering an area of an acre to a depth of 3 feet, according to Chas. V. Averill. Mr. E. S. McClellan, who owned and farmed the land in 1941, had used some of the limestone on the land and claimed an analysis indicated the tufa contains 99 percent $CaCO_3$.

Moore deposit is on Jacoby Creek about 5 miles southeast of Bayside. In 1913 some of it was quarried for local use on farm lands. A sample analyzed for the State Mining Bureau at that time by Miller & Brown Company, San Francisco, gave the following results (Lowell, F. L. 16, p. 394):

	Percent
Silica	1.41
CaO 53.61%; $CaCO_3$	95.74
Fe_2O_3	0.35
Al_2O_3	0.56
MgO	trace
Water	0.01
Residue from carbonaceous matter	0.50
(volatile, CO_2, H_2O, etc.)	42.40

Rickter deposit is in the SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 11, T. 1 N., R. 1 W., 2$\frac{1}{4}$ miles by road from Rio Dell, and about 3 miles from the Northwestern Pacific Railway. It has been quarried for agricultural use. According to a report by Charles V. Averill (41, p. 517) the quarry was 75 feet long, but the maximum depth reached in the limestone was only 25 feet. He stated the deposit might have a total length of 1000 feet, but stripping of overburden would be required to prove this. Backs of 100 feet could

be had from the old quarry floor if the limestone extends that deep ahead of the present face, as the ridge rises beyond the quarry.

The deposit is soft limestone close to a fault contact between the Franciscan (?) and Pliocene marine sediments.

Three Creeks prospect is in sec. 33, T. 7 N., R. 4 E., over 20 miles east of Korbel, the nearest railroad point. The prospect consisted of boulders of limestone, some several tons in weight, strewn over areas totalling a few acres (Averill, C. V. 41, p. 517). No development had been done. This limestone has been classified as Devonian by Harry McGinitie, Humboldt State College.

White Rock deposit is in secs. 18, 19, T. 6 N., R. 5 E., about 5 miles south of Willow Creek P. O. near the eastern side of the county. Willow Creek, on state road 299, is 33 miles east of Korbel. This is apparently the largest deposit of limestone so far described in the county, being part of a series of limestone lenses which outcrop at intervals for a distance of many miles, striking north-northwest about parallel to the South Fork of Trinity River. This limestone was formerly listed as Devonian but the age may be in doubt as the deposit is near the indefinite western border of an area shown on the current state geologic map (Jenkins, O. P. 38) as pre-Cambrian, and on an earlier state map (Smith, J. P. 16) as Paleozoic metamorphics, undifferentiated.

The deposit forms the top of a ridge and is reported to outcrop for a length of 800 feet over a width of 145 feet, and stands 50 feet high. It lies well for quarrying.

The following analysis was made for Alexander Brizard, Arcata (who claimed the land in 1940), by Smith Emery & Company (Averill, C. V. 41, p. 518):

	Percent
SiO_2	0.34
Al_2O_3	0.16
Fe_2O_3	0.13
MgO	0.53
CaO	54.88
Purity as $CaCO_3$	97.95

White Woman deposit is in secs. 20, 29, T. 4 S., R. 5 E., about 8 miles by road south of Alder Point on the Northwestern Pacific Railroad and near Harris P. O. Small outcrops of limestone of apparently good quality are reported.

Imperial County

Until 1907, Imperial County was a part of San Diego County. There has so far been little development of the large deposits of limestone and marble in the county. The only recorded production in recent years was in 1939 and 1940. Previously, about 1920, some marble was produced. The most important deposits so far noted are along the west side of the county, in the Fish Creek Mountains, secs. 1 and 12, T. 14 S., R. 9 E., about 16 miles from a broad-gauge railroad, and in the Coyote Mountains in T. 15 and 16 S., R. 9 E., S.B. The latter are within 5 to 7 miles from the San Diego and Arizona Railroad, which connects San Diego with the populous Imperial Valley, and have been the only deposits to receive any attention so far. In the northeastern part of the county

are several large areas covered by pre-Cambrian and pre-Cretaceous metamorphics in which dolomite and limestone might occur, though not so far reported.

Besides these hard limestone deposits, there are some areas in the southwestern part of the county that are noted for shell deposits. These are between the state highway and the Mexican border.

Coyote Mountains Limestone. About 1923, Columbia Cement Company was organized to promote development of the Coyote Mountain deposits for making cement. The company consolidated about 8000 acres, extending from sec. 22, T. 15 S., R. 9 E., southeastward through sec. 1, T. 16 S., R. 9 E., S.B. There is no record of the work done, if any, on the deposits. The corporation was suspended as of March 8, 1932 for failure to pay the corporation franchise tax. In the consolidation, they were said to have taken over holdings of Southern California Marble Company 6½ miles north of Coyote Wells; Golden State Mining and Marble Company; Schrader and Moore holdings, and others. Some of these are mentioned below under later owners.

The larger limestone bodies are (1) on the north, running southeast from the SW¼ sec. 22 nearly to the south line of sec. 25, T. 15 S., R. 9 E., or about 3 miles long by ½ mile wide; (2) from the SE¼ sec. 27 to the SW¼ sec. 36, T. 15 S., R. 9 E., and (3) most of N½ sec. 2, T. 16 S., R. 9. E. There are also several smaller bodies. The vertical range is from 800 or 1000 feet to 1700 feet in (1) and to 2335 feet on the top of Coyote Mountain in (2).

The beds of limestone or marble, commonly blue gray, are steeply tilted, dipping 70° NE. They are interbedded with micaceous schist. The total amount available has been estimated at 600,000,000 tons (Tucker, W. B. 26, p. 276). Originally, interest was devoted principally to the deposits as sources of marble, and F. J. H. Merrill (16) described in detail several deposits of various colors ranging from blue black through mottled black and white to red, pink, yellow and white.

The few analyses of this limestone that are available indicate it is a high-calcium stone, but the manner in which samples were taken is unknown, and they should probably be considered as picked samples. Analysis 1 below is from Merrill (16) and was made by F. Salathe; 2 and 3 are from Tucker (26) and were made by Smith Emery & Company, Los Angeles.

Analysis 1	Percent
$CaCO_3$	96.6
$MgCO_3$	1.7
SiO_2	trace
Fe_2O_3 and Al_2O_3	0.9
$CaSO_4$	0.5

	Analysis 2 (white) Percent	Analysis 3 (blue) Percent
SiO_2	1.00	1.08
Fe_2O_3	0.05	0.02
Al_2O_3	0.76	trace
CaO	54.32	54.00
MgO	1.78	1.48
Ignition loss	42.05	43.40

The basement rocks on which the limestone rests now are the Jurassic acid intrusives (granitic) of the extreme southeast end of the Peninsular Ranges which intruded and elevated the pre-existing sediments.

Large supplies of clay, said to be suitable for use in making portland cement, occur near the limestone on both the east and west sides of the mountain.

Creole marble deposit is on 80 acres (4 claims) in secs. 25 and NE¼ sec. 36, T. 15 S., R. 9 E., S.B. The owners in 1942 were Henry L. Jackson, Brawley, and Phillip W. Knights, El Centro.

These deposits have been known for 40 years, and Golden State Mining and Marble Company did some work on them years ago. The marble outcrop is reported 4500 feet long by 600 feet wide and is estimated to contain 3,000,000 cubic feet of commercial marble. F. J. H. Merrill (16) mentioned three distinct strata of marble here—a deep blue black, free from quartz or chert; a cream-pink layer with some blotches of red and black lines; and a white marble with green veining, this being in small blocks. Only assessment work has been done recently. The San Diego and Arizona Railroad line is 6 miles south of deposits.

Dixieland limestone claim (160 acres) in secs. 31 and 32, T. 13 S., R. 9 E., S.B., was held in 1926 by W. A. Waters, Pasadena. It is in the Fish Creek Mountains about 16 miles northwest of Coyote Wells, and near the gypsum mine which is served by a narrow-gauge railroad running to Plaster City. W. B. Tucker (26, p. 277) quoted the following analysis made by John T. Rice, El Centro:

	Percent
$CaCO_3$	90.02
$MgCO_3$	0.39
Fe_2O_3 and Al_2O_3	0.72
Insoluble	6.43

This and the Waters deposit are geologically similar to those in the Coyote Mountains, lying on the Jurassic acid intrusive (granitic) rocks at the eastern extremity of the Peninsular Range.

L & S (Jumbo) limestone deposit is in sec. 31, T. 15 S., R. 9 E., 5 miles northeast of Dos Cabezas on the San Diego and Arizona Railroad. C. H. Lunsford Estate and F. W. Sterns, San Diego were owners in 1942. Sampson (42) states the outcrop is 1 mile long by half a mile wide, elevation 1700 feet. The limestone is white and analyses are said to show from 94 to 98 percent $CaCO_3$ and from a trace to 2 percent $MgCO_3$. The quarry was equipped in 1942 with loading bins, cars and track but there is no record of production.

Mountain Springs limestone deposit is in sec. 28, T. 17 S., R. 9 E., S.B., 1½ miles southeast of the state highway and 8 miles southwest of Coyote Wells, in the southwest corner of the county. The holdings cover 160 acres.

The limestone beds strike N. 30° E., dip 60° SW., and are interstratified with schist. The thickness is reported to be 200 feet, but the analysis is not available.

Over 20 years ago the deposit was worked by the Duralite Products Company of San Diego. In 1939 and 1940, Tycrete Chemical Corporation, Chula Vista, San Diego County, worked the property, and this is the only limestone production recorded from Imperial County since 1922, when some marble was sold from another property.

Southern California Development Company marble deposit is on 80 acres in sec. 1, T. 16 S., R. 9 E. and sec. 36, T. 15 S., R. 9 E., S.B., 6 miles north of the point where the state highway crosses the San Diego and Arizona Railroad (3 miles west of Coyote Wells). Henry L. Jackson,

Brawley and Phillip W. Knights, El Centro were listed as owners by Sampson (42). The company first named opened the deposit and made some production in 1922 and earlier. The outcrops are 150 to 200 feet high, up to 200 feet thick, and estimated to contain 200,000,000 cubic feet of commercial marble. No recent work has been reported.

Waters limestone deposit is in secs. 1 and 12, T. 14 S., R. 9 E., S.B., 16 miles west of north in an air line from Coyote Wells, the nearest broad-gauge railroad point. The narrow-gauge railroad connecting the nearby gypsum mine with Plaster City also on the broad-gauge railroad, passes 3 miles east of the limestone. In 1942, W. A. Waters, Pasadena, was listed as holding 7 claims, acreage not given.

The blue-gray crystalline limestone strikes N. 30° W. and dips 65° NE. along the top of the Fish Creek Mountains, elevation 1000 to 1600 feet. W. B. Tucker (26, p. 277) states the limestone belt is 3 miles long by a mile wide and is exposed for a depth of 600 feet. Tucker (26) gave this analysis by John T. Rice, El Centro:

	Percent
$CaCO_3$	98.02
$MgCO_3$	0.77
Fe_2O_3 and Al_2O_3	0.83
Insoluble	0.34

Inyo County

Limestone and dolomite occur abundantly in Inyo County, but so far their commercial utilization has been limited. One area is immediately east of Shoshone, in the southeast corner of the county. Although the sections here indicate thousands of feet in thickness of limestone and dolomite (Hazzard, J.C. 37a), there is no production of either from the district. This area, which is small in comparison with others further north and west in the county, is about 30 miles long. An area extending over 50 miles northward from the vicinity of the Inyo Marble Company deposit near Swansea at the north end of Owens Lake, contains large quantities of limestone and dolomite ranging in age from Cambrian through Silurian, Devonian, and Carboniferous, into the Triassic. This region ranges in elevation from 4000 to over 10,000 feet and is served by a narrow-gauge railroad running from Keeler northward to Laws along the east side of Owens Valley within a few miles by road from much of this limestone. At Owenyo, 10 miles north of Owens Lake, this railroad connects with the Southern Pacific broad-gauge railroad running south to Mojave. Such shipments of limestone and dolomite as have been recorded during the past 20 years have come from Zurich and Cartago in this region. However, the limestone here has been of more interest commercially as the site of lead-silver ores, which occur in it near intrusive igneous contacts. The Cerro Gordo ores, for example, occur in Devonian limestone which has been intruded by monzonite porphyry, diabase, and quartz diorite porphyry, according to W. B. Tucker and R. J. Sampson (38, p. 432).

Other extensive areas where limestone is plentiful and is important as a wall rock for lead-silver ores include the Darwin district, where Pennsylvanian limestone occurs; the Panamint district, where different ages of Paleozoic limestone and dolomitic marble of varying degrees of purity are found, and several other mountain ranges. Only the first two

districts are near enough to railroads to be considered now as possible commercial sources of limestone and dolomite.

The latest published geologic work on the region is that of Richard G. Hopper (47). His section was taken across the south half of Inyo County. The article summarizes previous information on the limestones and dolomites and adds new details all tending to emphasize the tremendous volume of such rocks in the region.

Badgley quarry, about 4 miles north of Keeler in sec. 24 (?), T. 16 S., R. 37 E., M.D. was worked about 1915-16. About 40 tons of dolomite was shipped weekly to the California Iron & Steel Company, Los Angeles. The dolomite here is shattered and only one man was employed to break up the blocks. This was part of the old Inyo Marble Company holdings and contained 80 acres, patented. A spur track from the narrow-gauge California & Nevada Railroad served the quarry. Present ownership is not known, but may be part of Inyo Marble Company.

Blue Star Mines, Limited, Room 510, 810 South Spring Street, Los Angeles, has been a producer of limestone since 1938. The limestone is mined in connection with their talc-mining operations from their claims on Big Pine Creek, 9 miles west of Big Pine.

Talc occurs in masses in serpentine or on the contact of serpentine and crystalline limestone. The limestone is quarried nearby, lowered on a tram down the mountainside to a bin and hauled 11 miles in trucks to the grinding plant at Zurich on the railroad.

Cartago Company, 8317 Beverly Boulevard, Los Angeles, has at Cartago a dump of dolomite and quicklime and air-slacked lime made from limestone which was burned some years ago to produce CO_2 gas for use in alkali works. According to J. C. Fryer of Cartago Company, some sales have been made for metallurgical use at mines in Inyo County, as well as for other purposes. The dump contains 50,000 to 75,000 tons. Cartago is a railroad point near the south end of Owens Lake. Inyo Chemical Company formerly operated a plant there for making sodium carbonates.

Cerro Gordo Deposit. For some time about 1926, limestone was produced from underground workings of the Cerro Gordo lead-silver mine, 8 miles east of Keeler, and was sent over a tramway to Keeler for railroad shipment to the plants of Natural Soda Products Company, 2 miles south of Keeler and to Clark Chemical Company, then at Bartlett, near the north end of the lake on the west side. Limestone and dolomite have been used to generate CO_2 gas for making sodium carbonate from the desert lake deposits in Owens Lake and Searles Lake.

Doodlebug and *Dolomite groups* of claims are in the South Park district 30 miles east of north from Trona and about 8 miles southeast of Ballarat. The owners are Ernest A. Slafter, Box 362, Trona; F. Zerby, Wilbur Harrison, and Harry Willey. Doodlebug group comprises 11 claims and Dolomite group 18 claims, a total of about 600 acres. The elevation is from 4000 to 5000 feet. Up to 50 gallons of water per minute is said to be available.

Slafter has been prospecting a seam of lead and silver ore on Doodlebug Nos. 1 and 2 claims. Equipment in 1945 consisted of an air compressor and drills, and a tramway was being installed. These

claims are probably examples of many others that have been located primarily for metals, but which contain immense quantities of limestone or dolomite. This property has not been visited by the writer, and the geology has not been mapped in detail. The owner claims there are several hundred million tons of dolomite with few intrusions and no overburden; much of it is marble. The reported $MgCO_3$ content is 45 to 45.32 percent.

Inyo Chemical Company shipped lime from Cartago from 1927-31. The company was one of those engaged in making soda ash and sodium bicarbonate from the Owens Lake deposits, and the lime remained from limestone or dolomite which has been burned to obtain CO_2 gas for use in carbonation.

Inyo Marble Company's deposits have been described in many Division of Mines reports since 1888, when the original company of this name began work. The marble is found on the southwest side of the Inyo Range from just east of Swansea on the narrow-gauge Nevada & California Railroad on the northeast side of Owens Lake, northwestward for several miles, rising steeply on the northeast from an elevation of 3700 feet. The railroad runs along the east side of the valley within less than 1 mile of the deposit for the entire distance.

Work by the original Inyo Marble Company began in 1888. Near the surface the marble was found to be shattered, but later work made it possible to take out blocks weighing from 15 to 18 tons each. The early work was on a dense, white marble, about 3 miles northwest of Swansea. A little south of this a bed of white, yellow, gray, and black marble was found. About half a mile north, a quarry was opened in yellow marble, and a quarry of black marble, used for floor tiling was also worked. Marble production in Inyo County was recorded in Division of Mines reports from 1894-98; from 1903-07 inclusive, and in 1913-14. The total for these periods was 78,400 cubic feet valued at $219,300, all believed to have come from this property. Later production of marble in the county continued irregularly until 1930, but details are concealed. During the early periods of production at least up to 1908, the rough marble was shipped north over the railroad to Truckee where the old company had a marble sawing and dressing plant. The marble was used in the Mills Building and others in San Francisco.

Sometime later, prior to 1916, the claims were idle and were allowed to lapse. They were relocated by the present owners who also took the name Inyo Marble Company. They filed on 24 association claims of 160 acres each. Of these, they have obtained patents for 320 acres in sections 10 and 11, 120 acres in section 24, and 40 acres in section 25, all in T. 16 S., R. 37 E., M. D.; also 200 acres in section 19 and 120 acres in section 30, both in T. 16 S., R. 38 E., M. D.

Most of the marble produced here has been white dolomite, fine grained and dense. W. A. Goodyear who wrote of the deposit in 1890 (see De Groot, H. 90, pp. 215-218) considered that it had possibilities as statuary marble because of its uniform white color and texture where opened 200 feet above the foot of the mountain. An analysis made in 1890 by the State Mining Bureau showed 54.25 percent $CaCO_3$, 44.45 percent $MgCO_3$ and 0.60 percent iron and silica, indicating a nearly pure dolomite.

From 1915 until recently, dolomite has been produced and sold to soda plants around Owens Lake, and some has been shipped to Los Angeles for use in steel furnace lining and flux, and for stucco dash and terrazo. Due to expiration of patent rights to another process for making sodium carbonates, firms that formerly used dolomite and limestone to produce CO_2 gas for carbonation are said to have been turning to the use of the formerly restricted process, and are no longer burning lime. The quarry that served these plants reached a length of 1000 feet or more, and employed 35 men 20 years ago. At that time, considerable work was also done on the Golden Yellow quarry. This marble is golden yellow, brown, and white. It was exposed for a distance of 150 feet and a height of 200 feet. Six quarries in all were opened. Besides an air compressor and crushing plant, the main (Alco) quarry was equipped with derricks and marble saws.

Rogers limestone deposit is 7 miles northeast of Laws, in Silver Canyon on the west side of the White Mountains. This quarry produced high-calcium limestone which was hauled by truck to the narrow-gauge railroad and shipped to soda plants on Owens Lake for production of CO_2 gas used in carbonation. No recent activity has been reported.

West End Chemical Company, Trona, has operated a quarry on a deposit of dolomitic limestone in the Slate Range, Inyo County, 12 miles northeast of Trona. The stone has been hauled in trucks to the company's plant on Searles Lake and burned to furnish CO_2 gas for use in making sodium bicarbonate and soda ash.

Kern County

For 30 years, from 1894 to 1924, lime production was a substantial item of mineral output from Kern County. Maximum production of 295,613 barrels was reported in 1906, but from that time on, there was a falling off, interrupted by short periods of prosperity, until 1928 when the last activity was reported from the Tehachapi district, where lime-burning had been centered.

Meanwhile, a cement plant was erected at Monolith on the railroad a few miles east of the Tehachapi summit, to produce Portland cement for use in building the Owens River-Los Angeles aqueduct. In 1921, this plant was taken over by Monolith Portland Cement Company and has since been operated as a private enterprise. In recent years it has been the only producer of limestone in the county, but all of its product has been used in making cement.

The southern termination of the Sierra Nevada Mountains is nearly coincident with the south boundary of Kern County, swinging southwest past Tehachapi to the vicinity of Lebec. The larger part of the eastern half of the county is occupied by granitic rock, mapped as Jurassic acid intrusives. None of the older Cambrian or Archean formations, found farther east in San Bernardino County, have been mapped in Kern County. The limestone deposits are part of the Kernville (Carboniferous?) series, which includes also quartzite, phyllite, and contact-metamorphic rocks. The geology of the Kernville quadrangle has been mapped by William J. Miller and Robert W. Webb (40), and it is believed that the extension of such detailed work to the south would show the same formations and relationships. The limestone and associated rocks occur

as roof pendants intruded by, or as elongate layers partly enfolded in the later intrusives, with the development of such contact minerals as wollastonite, garnet, and tremolite. The great variety of intrusives, ranging from very basic to highly silicic, ended with the coming of the Isabella granodiorite. Subsequent erosion has removed such a great volume of rocks that this once deeply buried Isabella granodiorite is exposed over wide areas, and the limestone remaining represents only a small part of the original beds.

The larger number of deposits so far mapped are in the two tiers of townships extending south from the northerly county line in R. 33 and 34 E., M.D. past Tehachapi. The most accessible and the only deposits so far developed are those near Tehachapi and Monolith.

Cuddy Canyon deposits are in the southern part of T. 9 N., R. 20 W., M.D., 8 miles south of west from Lebec, on a ridge on the north side of Cuddy Canyon at an elevation of about 5300 feet. This is a prominent part of the highly crystalline limestone outcropping in granite, first mentioned by H. W. Fairbanks (94, p. 495) as extending in numerous detached areas from the vicinity of Gorman westward. On the three claims held by Henry Kramer in 1929, the limestone is said to be exposed for 4500 feet with a width of about 300 feet. It is white, high-calcium stone. So far as known no work has been done on it. Castaic, about 45 miles south by state highway, is the nearest railroad point.

Erskine Creek limestone deposits extend along Erskine Creek in the eastern part of T. 27 S., R. 33 E., M.D., the southwestern part of T. 27 S., R. 34 E., and the western part of T. 28 S., R. 34 E., M.D. The deposits are from 30 to 36 miles by road from Caliente, the nearest railroad point, and at elevations ranging from 4000 to 7000 feet. The outcrops are not continuous, being interrupted by intrusive rocks. The strike is N. 40° W. and dip very steep. The limestone ranges in character from hard marble to sandy, more or less siliceous stone. No development of the limestone as such has been reported (Brown 16, p. 517).

Jameson Lime Company began work in 1903 on a large deposit of limestone in W½ sec. 14, T. 32 S., R. 33 E., M.D., 3 miles northeast of Tehachapi. For many years they operated two lime kilns. About 1920 the property passed to Blue Diamond Plaster Company. This is the same section where Monolith Portland Cement Company later opened a large quarry. The limestone is coarsely crystalline, generally blue but in part white, or blue and white. It is in a hill rising 400 feet, and is half a mile wide.

Monolith Portland Cement Company, 215 West Seventh Street, Los Angeles, in 1921 took over the operation of the cement plant that had been built and operated previously by the city of Los Angeles to furnish portland cement for use in the aqueduct from Owens River. The plant is on the railroad at Monolith a few miles east of Tehachapi summit. It is a wet-process plant with an annual capacity of 2,000,000 barrels. The plant was described in detail by Tucker (29).

The limestone deposit originally worked and in part still available is on 160 acres owned by the company in sec. 14, T. 32 S., R. 33 E., M.D., 4 miles by road northwest of the plant. There a quarry face 1500 feet long and several hundred feet high was opened. Later 2500 acres of

limestone lands were taken under a long-term lease, and this is being worked on royalty.

Mountain Minerals dolomite deposit is covered by four locations, 1200 feet by 3000 feet, made in September and October 1943 by Vetta V. Bartholemew, c/o McCarty Brothers, Taft, California. The claims are in Piru district 34 miles southeast of a railroad, at 6000 to 7000 feet elevation, in rugged country. The nearest town is Maricopa. There is some pine timber and three springs, and a surfaced highway passes within 1½ miles of claims. The owner claims to have a very large deposit with an MgO content of 21 percent.

Mountain Summit limestone deposit is near Keene, a railroad station west of Tehachapi. The Mountain Summit Lime Company burned lime from the deposit 30 to 40 years ago, but there has been no recent production.

South Fork Valley extends east from Isabella, where the South Fork joins the main Kern River. From a point on the South Fork about 4 miles east of Isabella, limestone outcrops within half a mile on the north and 1 mile south of the stream. On the north, limestone extends 3 miles northeast, and to the south the interrupted outcrops can be followed southeastward for nearly 10 miles. These deposits are 35 to 45 miles by road from the nearest railroad point at Caliente and have never been developed. The limestone is associated with mica schist, phyllite, and quartzite and has been largely changed to marble. The marble beds are in places several hundred feet wide.

Tardy limestone deposit is 3 miles west of Cinco, a point on the Southern Pacific Railroad 17 miles northeast of Mojave. This is near the Garlock fault, at the extreme southeast side of the Sierra Nevada granitic area.

Union Lime Company whose last known address was 1326 North Maryland Avenue, Glendale, but which was suspended as of March 5, 1937, for many years held 1720 acres, patented, in and adjoining sec. 35, T. 12 N., R. 15 W., S.B., 3 to 4 miles south of Tehachapi. The company was the largest lime producer in the county and was in operation at least as early as 1896 and as lessee of Summit Lime Company reported production up to 1928. They operated as many as eight lime kilns with a total capacity of 560 barrels a day and a crew of 50 men. The continuous kilns in early days were fired by oak wood which was abundant locally, but toward the end of operations natural gas was used. The last four kilns received 45 tons of sorted limestone in an 8-hour shift. These kilns were near the quarry and a lime hydrate plant with a capacity of 8 to 9 tons a day was located at Tehachapi.

The limestone deposit is 4000 feet long by about 500 feet thick. It is thought to be in a compressed syncline in granodiorite. It is interbedded with (biotite?) mica schist and the two have been considerably crushed, which caused increased quarrying cost. The deposit is at the south edge of Tehachapi Valley and the main Garlock fault is about 3 miles southeast, so there may possibly be a fault wedge partly occupied by the limestone. It is a high-calcium, finely to coarsely crystalline, white to bluish limestone, and the lime made from it was widely and

favorably known, as the district was the principal source of lime for southern California for many years. The limestone is said to have carried about 98 percent $CaCO_3$ and 2 percent SiO_2.

Several quarries were worked, one of which had a face 300 feet high.

Lake County

Small quantities of lime were burned in Lake County for local use, especially at the quicksilver-reduction plants. No large deposits are known to occur in the county. Lake County has no railroad lines and the population in 1940 was slightly over 8000.

Some limestone has been reported near the Abbott quicksilver mine, near the east county line in the southwest part of T. 14 N., R. 5 W., M.D. In Burns Valley, near the present Clear Lake Park, lime kilns were once operated. Occasional masses of limestone may be found loose in this region. Limestone occurs in sec. 19, T. 11 N., R. 7 W., M.D. There are the remains of an old stone lime kiln in sec. 36, T. 13 N., R. 6 W., M. D., which was used many years ago to burn limestone from a small deposit nearby.

Los Angeles County

Most of the limestone and lime products used in the Los Angeles area have been shipped in, coming in part from Arizona and Nevada, and in part from neighboring counties. However, there are some interesting limestone deposits in the younger geologic formations, and several small deposits of limestone and dolomitic limestone have been noted in the pre-Tertiary crystalline rocks of the Little Tujunga quadrangle in the western part of the San Gabriel Mountains. There has been some production of limestone in recent years at Bel-Air and Palmdale, and in the late twenties at Torrance.

Algal Limestone

Santa Ynez Deposit. The most interesting and probably most important limestone deposit in the county is on the west slope of the Santa Monica Mountains at elevations of 1100 to 1400 feet on Rancho San Vicente y Santa Monica, 2½ to 3 miles north of Castellamare. It is in the Martinez formation (Paleocene) in the Reseda and Topanga Canyon quadrangles of the U. S. Geological Survey and has been described as follows by H. W. Hoots (31):

> ". . . Near the head of Santa Ynez Canyon the Martinez formation has an approximate thickness of 250 to 350 feet . . . The algal limestone is one of the most striking and probably the most unusual rock types in the Santa Monica Mountains. It occurs in prominent white reefs from a few feet to several hundred feet thick which vary in lateral extent from only a few feet to about 4000 feet and commonly terminate in an abrupt wall. . . . This limestone is distinctly nodular and has irregular bedding. Although weathered outcrops are commonly white, some black or very dark gray algal limestone and fresh exposures of even the white-weathering rock have a characteristically spotted appearance due to the abundance of nearly white irregularly shaped algae and algal colonies embedded in a limestone matrix of light brown or gray color. In some places there appear to be all grades of purity of this limestone, a condition which may be noted in single outcrops or even in hand specimens where comparatively pure white or light brown algal limestone grades laterally or vertically into a darker gray algal rock with a matrix that is highly argillaceous. . . ."

According to an unpublished field report by W. B. Tucker, District Mining Engineer, State Division of Mines, this limestone and the shale near it were investigated in 1928 by Los Angeles Mountain Park Company as sources of material for Portland cement. The largest reef of limestone is reported 4000 feet long and up to 700 feet thick. Tucker quotes the following analysis made by Raymond Laboratories, Los Angeles:

	Percent
SiO_2	3.56
Al_2O_3	0.94
Fe_2O_3	1.86
CaO	50.66
MgO	2.13
Loss on ignition	40.55

The Santa Ynez quarry was opened at that time and showed a thickness of 50 to 100 feet and a shaft 200 feet deep on 45° incline passed through limestone into limey shale. This bed is about 2000 feet long. Since 1936, W. F. Glasser, Inc., 713 North Sepulveda, Brentwood Heights, Los Angeles, has been producing limestone from this deposit.

Palos Verdes Deposit. On the grant of the same name, in the San Pedro Hills southwest of Lomita, fossiliferous limestone was produced for 3 years, 1927-29 inclusive, by Torrance Lime & Fertilizer Company. It was used principally by Pioneer Compost Company and also by citrus fruit growers on adobe soils. Although stated to carry 70 percent $CaCO_3$, an analysis quoted by Tucker (27, p. 328) as having been made by Smith Emery & Company, showed the following:

	Percent
Fe_2O_3	0.57
Al_2O_3	0.74
CaO	49.21
MgO	2.26
(K_2O, Na_2O)	0.44
CO_2	39.23
SO_3	0.13
P_2O_5	0.73
Moisture (below 105° C.)	0.17
Combined water (over 165° C.)	2.89
Acid insoluble matter	3.63

These fossil beds are reported to be 30 feet thick and are covered by 12 feet of adobe soil. They are probably Quaternary (Pliocene).

Dolomitic Limestone

Gordon B. Oakeshott (37, pp. 220-221) has described some small deposits of dolomitic limestone, some of it approaching true dolomite. These are roof pendants and inclusions, representing the remains of what he thinks was once a thick and extensive deposit. He places them in the Placerita meta-sediments, (Carboniferous?). The deposits are in T. 3 N., R. 14 W., S.B., a few miles north of San Fernando.

The following is quoted from Oakeshott's article:

". . . Megascopically, it is usually a medium- to coarse-grained white marble. Crystals of calcite up to a half inch in length are common. Fine-grained limestone is found, but all of it has been recrystallized. Not all of it is pure calcite, but much of it indicates by color and composition derivation from calcareous argillaceous and arenaceous sediments. One of the commonest accessory minerals is graphite which occurs in small flakes in the limestone in varying percentages. Near the contacts with intruding diorite and granodiorite, contact metamorphic minerals are often developed.

Particularly common are tremolite, brown and red garnet, epidote and diopside . . . A small percentage . . . is strongly zoned and is probably dolomite. However, typical dolomite rhombs are not present. The mineral composition indicates derivation from a dolomitic limestone carrying a small percentage of clay.

"Five typical analyses were made by Mr. Merle Slykhous, instructor in quantitative analysis at Compton Junior College . . . The 'insoluble' is mainly graphite and silica.

Sample	*Percent CaO*	*Percent MgO*	*Percent CO_2*	*Percent insoluble*
95D	46.1	5.9	38.4	10.5
126A	38.7	20.3	40.5	0.7
96-7	54.1	0.4	42.0	2.8
126B	36.7	16.8	46.4	0.3
95-3	36.5	13.9	40.0	9.2"

Baughman dolomite deposit is in secs. 7 and 18, T. 3 N., R. 14 W., S.B., on a ridge northwest of Pacoima Canyon. This is a belt of white crystalline dolomite, originally reported to be 3000 feet long and 300 feet wide. Actual dimensions of the outcrop are not over one-quarter those indicated. Strike is west-northwest and dip steeply toward the north.

Haskins dolomite deposit comprises 5 claims and millsite $3\frac{1}{2}$ miles north of Sunland in sec. 28, T. 3 N., R. 14 W., S.B., on slope of ridge northeast of Little Tujunga Canyon, elevation 2000 to 2700 feet. Both Oakeshott (37, p. 244) and Reid J. Sampson (37, pp. 202-203) have described this property, on which some development was done prior to 1937. It is not mentioned in later bulletins as a producer. Quarry No. 1 on Lady Helen claim is on a body of dolomite 150 feet long.

On the Lone Jack claim there is an outcrop 50 feet thick by 200 feet long, prospected by an open-cut. Other smaller outcrops were mentioned.

The following analyses were quoted by Sampson; both were made by Baverstock & Payne, Los Angeles.

Sample	*Percent CaO*	*Percent $CaCO_3$(equivalent)*	*Percent MgO*	*Percent $MgCO_3$(equivalent)*
1	32.75	58.20	17.2	36.00
2	49.3	87.8	4.0	8.4

Ramelli deposit is in sec. 17, T. 3 N., R. 14 W., S.B., at 2200 feet elevation. It is reported to be 300 feet long by 50 feet wide.

San Fernando deposit is in sec. 19, T. 3 N., R. 14 W., S.B., about 3000 feet southeast of Pacoima dam. Some work has been done on it.

Madera County

There has been no recorded production of limestone from Madera County, but there is ample evidence of the occurrence of more or less siliceous limestone and marble in the number of prospects of scheelite in tactite which were found during the last war. Most of these are so far from railroads that there seems little probability they will prove of interest as sources of limestone. A list of these scheelite prospects with their locations is given by Jenkins (42, pp. 333-337). Most of them are in the three tiers of townships in R. 22, 23, 24 E., M.D. which are in the high Sierra Nevada region and in part astride the summit. The westernmost deposits (those nearest the railroad) are described below.

Chowchilla marble deposit is 3 miles from Grub Gulch on Chowchilla River, probably in the northwest corner of T. 7 S., R. 20 E., M.D. It has been known for many years and has not been developed. It is 15 or 16 miles by road from Raymond; but the nearest railroad point now is Daulton about 8 miles south of Raymond.

R. & W. Tungsten Company claims in secs. 24 and 25, T. 7 S., R. 20 E., M.D., have made some scheelite production, but the extent of the limestone outcrops is not known. These claims are 2 to 3 miles northwest of Coarsegold.

Scott marble deposit is 6 miles east of Coarsegold. The marble beds include a banded green and pink siliceous dolomitic marble.

Marin County

There was some early-day production of lime in Marin County, but limestone has not been produced for 50 years, and is not generally listed among the mineral resources of Marin County. Nevertheless, an important deposit of Gavilan (Paleozoic?) limestone occurs at the head of Tomales Bay, and a deposit of Calera (Franciscan) limestone has been noted south of Olema on the road to Bolinas. Both were described by Edwin C. Eckel (33, pp. 353, 356). They are called here for convenience *Tomales Bay deposit* and *Olema deposit,* and the following notes and analyses are from Eckel's report.

Olema deposit of Franciscan limestone is several miles south of Olema on the Bolinas road. There are remains of three old lime kilns which are said to have been used by the Russians during their sojourn on this coast about 1825. The size of trees growing in the kilns at the time of Eckel's visit indicated they had not been used since 1875. The limestone beds he found were covered by debris, except at one side, and the exposure showed about 50 feet of workable thickness and 100 feet along the outcrop of limestone. He believed that the topography suggested the possibility that the belt might run for several miles along the valley, with a greater thickness than now visible. From the analyses given below, it will be seen that the limestone is low in silica and magnesia and higher in $CaCO_3$ than most other deposits of Calera limestone.

Sample 1 was taken by Junea Kelly and analyzed by U.S. Bureau of Standards; No. 2 was sampled and analyzed by C. A. Newhall. Fairfax, the nearest railroad point, is about 15 miles east.

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	CO_2
1	1.1%	0.68%	incl.	97.98%	54.8%	n. d.	trace	43.2%
2	1.90	0.76	0.20	96.74	n. d.	0.33	n. d.	n. d.

Tomales Bay deposit lies about half a mile west of Tomales Bay. The outcrop is about 1 mile long north to south by half a mile wide near the head of the bay, according to Eckel. It is Gavilan limestone, cut off by the Montara granite on the north and east and covered on the southwest by Miocene shale. The area of exposed limestone is 300 to 400 acres, on Rancho Punto de los Reyes. The limestone was quarried at several places to make lime, probably 40 to 50 years ago. The beds show a steep dip and have a vertical range of 300 feet or more. The deposit is about 4 miles inland from Drake's Bay and about 15 miles by road from Fairfax on the Northwestern Pacific Railroad.

The following analyses of limestone from this deposit as quoted by Eckel, were taken and analyzed as follows: (1) no. 1, from old quarry near Trout Farm, sampled and analyzed by C. A. Newhall; (2) no. 2, from Lockhart Tract near Inverness Park, sampled and analyzed by C. A. Newhall; (3) no. 3, from Lockhart Tract near Inverness Park, sampled by E. C. Eckel and analyzed by U. S. Bureau of Standards; (4) no. 4, from near Inverness Park, sampled and analyzed by F. Huber.

No.	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	CO_2
1	1.66	0.44	0.20	96.60	n. d.	0.75	n. d.	n. d.
2	2.26	0.55	0.25	95.48	n. d.	1.10	n. d.	n. d.
3	2.3	0.76	incl.	96.0	53.8	n. d.	0.35	42.7
4	1.3	0.3	incl.	97.0	54.32	n. d.	1.25	42.68

Mariposa County

From 1927-44, limestone was quarried in Mariposa County for making portland cement at a plant near Merced. There is no other record of production. The Yosemite Valley Railroad which connected with two mainline railroads at Merced and followed the winding course of Merced River to El Portal, discontinued freight service, depriving the county of its only rail outlet. The long truck haul to outside points would be a handicap.

The Carboniferous (Mississippian?) beds so rich in limestone in Tuolumne County extend southeastward through Mariposa County, but only the northwest part has been mapped in detail. The geologic map of this area shows only two lenses of limestone at and near Bower Cave. Other large deposits exist farther south and east at Briceburg, near Hite Cove, and at Jenkins Hill, the last being the only deposit so far worked.

Bower Cave deposits are two good-sized lenses of limestone extending southeast for a total distance of about 2 miles from Bower Cave, a small cavern in limestone on the North Fork of Merced River in sec. 19, T. 2 S., R. 18 E., about 10 miles east of Coulterville.

Cotton Creek deposit is a small body of limestone in the Mariposa (Jurassic) slate in sec. 18, T. 4 S., R. 16 E., M.D., just north of Cotton Creek.

Emory quarry is at Jenkins Hill on the north side of Merced River in secs. 7 and 8, T. 3 S., R. 19 E., M.D. For 17 years it was the source of limestone for Yosemite Portland Cement Corporation which operated a plant 2 miles from Merced from 1927-44, when operation ended and the cement plant was removed.

The limestone quarry floor is 800 feet above the railroad tracks. The outcrop rose several hundred feet higher and extended for half a mile. The stone was broken to pass 1 inch before being lowered for loading on railroad cars in which it was shipped 63 miles to the cement plant.

The cement plant was described in detail in *Rock Products,* June 11, 1927.

W. M. Frew, Ben Hur Post Office, has reported having a large deposit of high-grade limestone. No details are available.

Marble Point deposit is in sec. 2, T. 4 S., R. 19 E., M.D., on the South Fork of Merced River. This has been mentioned by Lowell (16a) as a

"very fine marble" and has been located as mineral but so far as known is undeveloped. It is 2½ miles south of the Yosemite Valley highway. The marble is white with dark veining and takes a high polish. The outcrop is reported to be 3000 feet wide, and rises 600 feet from the river. At Hite Cove, 2 miles northwest on the same stream, H. W. Turner (94, p. 446) reported the finding of the fossil *Fusulina*, which has a range from the Permian to the lower Carboniferous.

A mile northeast of Mount Bullion, on the Mariposa Grant, there is a small outcrop of limestone in a lens of Calaveras rocks.

O'Brien limestone deposit is in N½ NE¼ sec. 11, T. 4 S., R. 18 E., M.D., about 1 mile from Briceburg, a point on the Merced-Yosemite Valley highway, and 50 miles from Merced. Miss Ethel R. O'Brien, 1534 Clay Street, San Francisco, and others, are the owners. The 80 acres of land is patented and rises about 800 feet above the highway on the southeast side of Merced River, which is about a mile distant. A road connects the deposit with the highway.

No production has been made from the deposit and it has not been developed sufficiently to prove tonnage, but the owners estimate some millions of tons are available. The limestone outcrops prominently on a steep slope and can be worked entirely by gravity. Electric power and water are available nearby.

The following analyses were made by Santa Cruz Portland Cement Company:

Analyses of O'Brien limestone, Mariposa County

	No. 1 (white) *Percent*	No. 2 (black) *Percent*	No. 3 (mottled) *Percent*
SiO_2	0.28	1.18	0.20
Al_2O_3 and Fe_2O_3	0.60	1.02	0.36
CaO	54.10	53.40	54.60
MgO	n.d.	n.d.	n.d.
Ignition loss	44.22	43.92	44.48
$CaCO_3$	96.54	95.29	97.44

Two-thirds of deposit is said to be of the mottled limestone (no. 3.)

Welsh and Forney deposit is 1½ miles from Bagby and within 1 mile of the line of Yosemite Valley Railroad which has, however, stopped freight service. The limestone outcrop is from 25 to 100 feet thick, 3,000 feet long and would give backs estimated at 200 feet. George Welsh and J. W. Forney, Bagby, were the last known owners.

Mendocino County

The larger part of Mendocino County is covered by the Franciscan (Jurassic) rocks, with a wide border of Cretaceous rocks along the coast. Neither of these groups is particularly favorable for furnishing large deposits of limestone in California although both do contain numerous small bodies and veins or stringers of calcite, limestone, and calcareous tufa. The only recorded production of limestone from the county was between 1930 and 1933 from a deposit near Laughlin.

Fisher Ranch Deposit. M. H. Fisher, Laytonville, is owner. The deposit is in W½ sec. 36, T. 22 N., R. 15 W., M.D., 2 miles north of Laytonville and a few yards east of the state highway, at an elevation of 1600 feet.

The limestone outcrops in two small hills separated by a saddle of 150 feet with no outcrops. The north hill is about 345 feet long from north to south and the width of outcrop is 105 feet though the hill slopes are wider. The south hill shows an outcrop 85 by 165 feet. The north outcrop is higher, rising 50 feet. No work has been done on the deposit and the owner was not aware of its nature.

The limestone varies in color from pink to yellowish gray and it is a fine-grained hard, dense stone of sub-conchoidal fracture. Parts of the deposit appear to be quite siliceous. Longvale on the Northwestern Pacific Railroad is 13 miles south by state highway.

Analysis by Abbot A. Hanks, Inc.

	Percent
Insoluble	5.56
Ferric and aluminic oxides	0.69
Calcium carbonate	93.16
Magnesium carbonate	0.39

Northwest Pacific Lime & Sulphur Company operated the Quinan Ranch deposit described below. Between 1930 and 1933, they produced and shipped some travertine and calcareous tufa.

Quinan Ranch deposit is owned by L. S. Quinan, Route 1, Box 377, Healdsburg, California, and is located in sec. 26, T. 17 N., R. 13 W., M.D. Formerly the product was hauled several miles to Laughlin on the Northwestern Pacific Railroad where the crushing plant stood, but the railroad passes within less than half a mile of deposit. The old road from the Quinan Ranch house is passable for an automobile to within half a mile of deposit.

This is a terrace deposit of travertine and calcareous tufa that was deposited by springs near the top of a ridge at an elevation of about 2000 feet. The springs, which still flow, but do not deposit appreciable amounts of mineral now, issue along a fault zone striking west and dipping 61° S. One terrace, west of the old workings, is 250 feet long by 100 feet wide, at 2000 feet elevation. The lower terrace, where work was done, is about 35 feet below the first, and east of it. It covered an acre or less. A pit 27 by 50 feet and 10 to 15 feet deep produced material used for agricultural purposes. This pit shows the travertine is 6 to 8 feet thick, underlain by soil and angular rock fragments. It was worked between 1930 and 1933 by Northwest Pacific Lime & Sulphur Company. Only a few steel rails remain at the pit.

All machinery has been removed from the building formerly used as a crushing plant at Laughlin, and the railroad company was planning in July 1945 to tear down the building.

Analysis by Abbot A. Hanks, Inc.

	Percent
Insoluble	3.20
Ferric and aluminic oxide	0.24
Calcium carbonate	94.97
Magnesium carbonate	1.51

Mono County

In the years when Bodie was an active mining camp, and a lumber railroad ran past the east side of Mono Lake to sawmills then in operation, lime was burned from chemical deposits of calcareous tufa which had been formed by springs rising beneath the waters of Quaternary Mono Lake. This lime was sold for use at the cyanide plants in Bodie for as much as $35 a ton. The last recorded lime production was in 1913.

These tufa deposits are often individually from 10 feet to 40 feet in diameter and may rise as high as 50 feet. Many of them now stand from 200 to 270 feet above the present lake level on the east and south sides of Mono Lake. One type of the tufa which has proved of special interest to geologists and mineralogists is thinolite. It is composed of interlaced yellowish or light-brown crystals of calcite, and forms one or more definite layers in the concentric succession of bands forming the deposits. The crystals have been regarded as pseudomorphs, but the identity of the original mineral has apparently not been established.

In the southeastern part of the county, east of the branch railroad running from Laws northward into Nevada, Cambrian rocks containing limestone outcrop for a length of 6 to 7 miles; and from there northward to the Nevada state line, pre-Cambrian metamorphics occur. Due to the abrupt fault scarp marking the west side of the White Mountains, the immense accumulations of granite debris poured out on the valley floor from the steep canyons on that side, and the danger of washouts and flash floods from these canyons, there are few if any roads in that direction, and little likelihood of interest in any possible limestone deposits there.

A limestone outcrop about 3000 feet wide occurs on the east side of Antelope Valley in the northeastern part of the county and, as mentioned by Eakle (19, p. 139), it has been changed to marble in large part. All of this is too remote to be of commercial value.

Limestone, marble and iceland spar in the southwestern part of the county have been described by Evans B. Mayo (34). Of particular interest among these are deposits of iceland spar found near the summit of Mount Baldwin. Some of the limestone in the region shows Devonian fossils and several periods in the Paleozoic are believed to be represented.

Near Bridgeport there are valuable deposits of travertine. This and the iceland spar last mentioned are of possible economic value at present.

Bridgeport travertine deposits are 1½ miles southeast of Bridgeport and 200 to 300 feet above the valley. In 1940, the owners were Charles L. Hayes, Bridgeport and Edward Dinneen, Oakland. They held 60 acres (Sampson, R. J. 40).

A quarry was opened in 1895 when California Travertine Company owned the property. Sixty tons of travertine was shipped in rough blocks to San Francisco where it was cut into slabs and polished and used in the rotunda of the old City Hall (Waring, G. A. 15, p. 134). The deposit is 50 miles from a railroad and apparently for that reason lay idle until 1926, when other quarries were opened and a carload of travertine was shipped to Oakland. No later shipments were reported.

The travertine was deposited in a number of ridges 5 to 30 feet high and somewhat thicker, which diverge roughly from a common point, with a length of several hundred feet. It is a handsome stone

when polished, showing shades of red brown and yellow, and is semi-translucent. The largest slabs obtained were reported 4½ feet by 6 feet.

Spar group of claims and *Spar King claim* are on unsurveyed land that would probably lie mostly in sec. 11, T. 5 S., R. 28 E., M. D. if surveyed. They are in the high mountains 5 miles south of the end of a road that terminates at Convict Lake, and lie on the west slope of Mount Baldwin, at an elevation of about 11,000 feet. They were located for iceland spar. According to Mayo (34), bodies of clear calcite in the form of lenses or huge druses, occur here in a zone of folding and faulting between 2 thrusts in crystalline limestone. The bodies of calcite are "several tens of feet in greatest dimension." Calcite occurs in huge crystals, cleavage pieces 1 foot in diameter having been taken. Euhedral quartz occurs with it. In 1932 several hundred pounds of the iceland spar was taken to Pasadena for testing, but so far as known there has been no commercial production.

Monterey County

Dolomite

The dolomite deposits in the foothills of the Gabilan Range in Monterey County near Natividad are more accessible and closer to the railroad than those on the other slope of the mountains in San Benito County, and have been worked on a larger scale. Production began in 1917 and continued at the rate of a few thousand tons annually up to the beginning of World War II. The manufacture of magnesium on this coast and the increase in production of steel during the war led to one large operation from which several hundred thousand tons of dolomite was produced. The only other operator of importance, and the only one to keep up regular production over a period of years has been a steel company which uses dolomite for lining basic open-hearth furnaces. Smaller tonnages, produced irregularly and used for terrazo, stucco dash, flux, lime, and CO_2 gas, have come from several other deposits not lately active.

Geological age and conditions are similar to those mentioned under San Benito County. The dolomite deposits and accompanying larger bodies of limestone are older than the pre-Franciscan granitic rock which has intruded and altered their lower beds, notably on Gabilan Peak, from which the limestone series takes its name. The limestone and dolomite beds, particularly on the lower slopes, as near Natividad, are remnants of what were probably much more extensive beds of the Sur series, described by Parker D. Trask (26, p. 134) and John E. Allen (46, pp. 17-21). The meager fossil remains found by Allen were insufficient to permit a determination of age of the limestone or even the nature of the organisms that built the deposit.

Permanente Metals Corporation, Permanente, California, produced dolomite on a large scale during the late war from a deposit 6½ miles by road northeast of Salinas. The deposit is in the lower foothills of the Gabilan Mountains near Natividad School, at less than 1000 feet elevation. Production has continued since the war, and the dolomite is treated at the Moss Landing plant to make magnesian refractories.

Work began in August 1942 and at time of visit in December 1943 the quarry was 500 feet wide, had been extended 200 feet into the hill and had a face about 175 feet high. Every 2 to 3 months a series of 10 churn-drill holes was put down 50 feet and blasted with bag powder.

A Marion $2\frac{1}{2}$-cubic-yard electric shovel loaded trucks which delivered rock to the primary crusher just below the quarry floor on the west slope. Material under three-quarters of an inch was rejected here and left in a waste pile, as it carried considerable fine, thoroughly decomposed granite, which occurs in the quarry in the form of small offshoots or dikes from the underlying Santa Lucia granite. The coarser dolomite, which was white and quite pure, was carried by a large belt conveyor to the plant at the foot of the hill, in part for finer crushing and storage in bins from which it was taken by belt conveyors to two 8- by 300-foot rotary kilns, and in part for shipment as crude dolomite. The portion that was calcined at 2000 degrees Fahrenheit was taken by truck 12 miles to the company's plant at Moss Landing, Monterey County, where it was treated with sea water, resulting in replacement of the calcium by magnesium, so that after thickening and filtration a cake of nearly pure magnesium hydroxide was obtained. This was calcined, giving 96 percent MgO, which was hauled to the Permanente plant at Permanente, Santa Clara County, for making magnesium by the Hansgirg process (see under *Magnesium).*

Crude dolomite was hauled $6\frac{1}{2}$ miles by truck to a loading silo at the railroad at Salinas, for shipment to the steel plant. More than half a million tons of dolomite was produced from this quarry to the end of 1944. Waste in quarrying was high, running close to 50 percent. For making magnesium, the company desired dolomite carrying over 20 percent MgO (theoretically pure dolomite would carry 21.86 percent MgO). The following analysis from the company checks quite closely with those for San Benito County deposits.

Analysis of dolomite, Permanente Metals Corporation

	Percent
CaO	31.7
MgO	20.5
SiO_2	1.0
Fe_2O_3	0.2
Al_2O_3	0.2
CO_2	46.4

The deposit is on the Sterling and Salmos Ranches and was worked under lease with a sliding scale of royalty.

Pacific Coast Steel Company prior to 1940, and thereafter Bethlehem Steel Company, 20th and Illinois Streets, San Francisco, have quarried dolomite for many years from a deposit on the Sterling Ranch in what would be sec. 2, T. 14 S., R. 3 E., M.D. if surveyed, about half a mile north of the Permanente quarry described above. Production has usually been comparatively small and for their own use in lining bottoms of open-hearth steel furnaces.

The following have been mentioned as small producers 20 to 25 years ago but not recently: H. Bardin, C. Z. Hebert, C. Patton, and Robert Porter, all of Salinas (Boalich, E. S. 21, p. 156).

Limestone

Limestone deposits are numerous in Monterey County and several have been worked in the past; but it has been years since commercial production was reported. The former operations have been described in early reports of the Division of Mines (Hanks, H. G. 84, p. 110; 86, pp. 29, 97; Irelan, W. Jr. 88, p. 410; Preston, E. M. 92, p. 260; Crawford, J. J.

94, p. 392; 96, p. 629; Aubury, L. E. 06, pp. 72, 73; Waring, C. A., 19, pp. 606-607; Laizure, C. McK 25, pp. 42-43; Fiedler, W. M. 44). More recently, students of geology have examined and described parts of the county (Trask, P.D. 26, Reiche, p. 37). Lime production stopped in 1910, and the last recorded output of limestone was in 1917. The early work was near Rockland Landing in T. 22 S., R. 4 E., where four kilns were operated in the eighties and early nineties, and lime was loaded onto steamers off-shore by means of an aerial tramway. Another early-day operation was in sec. 16, T. 18 S., R. 1 E., on Bixby Creek only 3 miles from the coast, where two or three kilns were operated from 1904-10. Farther inland, 6 to 12 miles northeast of Salinas, where dolomite has recently been quarried, considerable limestone was produced for use in beet-sugar factories.

The limestone deposits are part of the Sur series which includes also schists, quartzite, and gneiss and is the oldest group of rocks in the region. They are pre-Franciscan according to reports of studies of them in nearby areas. Most of the limestone bodies near the coast are small. The exceptions are the Pico Blanco deposit, 5 miles east of Point Sur, which has not been worked; and the deposits previously mentioned, near Rockland Landing and Bixby Landing, which have long been abandoned. The limestone has been altered to marble, which ranges in purity from almost pure $CaCO_3$ to 70 percent or less $CaCO_3$ with high percentage of diopside, feldspars, and other products of metamorphism. The grain size varies from fine to very coarse. In general, the beds of marble are usually not over 50 feet, and rarely 100 feet thick, and they are longest in a northwesterly direction, conforming to the structure of the enclosing rocks.

The coastal ridges in which so many deposits occur over an airline distance of about 32 miles between Bixby Creek on the north and Mill Creek on the south, are rough and steep. One state road follows the coast the entire distance and there are no roads connecting with the railroad and main highway on the east. The only outlet for limestone from this region would be to the coast, where lime was once loaded directly on ships. Deposits in the eastern and northeastern part of the county are within reach of the railroad, and those on the slopes of Gabilan (Fremont) Peak are located so they will ultimately be available for use in the cement plant near San Juan Bautista. These latter deposits are similar to those described under San Benito County. The map shows location of most deposits in the county.

The following are locations of deposits worked before 1910 in the region northeast and east of Salinas, principally for use in beet-sugar refining. None of the local limestone has been so used in recent years.

Alisal Ranch, about 5 miles east of Salinas.

Kellogg Ranch, 16 miles south of east of Salinas.

Natividad Ranch, 6 miles northeast of Salinas, close to the dolomite quarry of Bethlehem Steel Company.

Just north of Natividad Ranch, limestone was quarried and hauled 1½ miles north to an old kiln near Gabilan Creek.

Of the following deposits, some have been worked as noted, and the rest are undeveloped.

Chalone Creek deposit is in the southeast part of T. 17 S., R. 7 E., about 6 miles east of Metz. It is undeveloped.

Gabilan Peak (Bardin) deposit on the south and west side of the peak, is now partly included in Fremont Peak State Park. This is a siliceous limestone in which small deposits of barite were worked between 1915-21.

Henry Cowell Lime and Cement Company for many years owned the Rockland Lime and Lumber Company deposits in secs. 14, 15, T. 22 S., R. 4 E., and the loading place in section 22 nearby, from which lime was loaded by an aerial tramway 1000 feet long onto vessels standing offshore. Part, if not all of this property is now within the boundaries of Hunter Liggett Military Reservation. Four limekilns were operated 3700 feet inland as early as the late eighties. The property has remained idle for over 40 years. The large deposits of limestone here have been so thoroughly broken by landslides that the canyon side is covered by a loose layer of angular limestone blocks. All of the limestone has been changed to marble. In this region it occurs over a vertical range of several hundred feet.

Jolon Deposit. E. B. Preston (92, p. 260), mentions a shell deposit "a few miles south of Jolon," which supplied material for a lime kiln operated some years earlier, which was then idle. Jolon is about 19 miles by road southwest of San Lucas.

Los Vergeles Ranch deposits are 11 to 13 miles northeast of Salinas on the highway to San Juan Bautista, on 250 acres of land. They are part of a group of limestone bodies which extend for over 6 miles at intervals from San Benito County westward. The highway crosses one of the outcrops about midway of the group, so that most of the limestone on both sides is within $2\frac{1}{2}$ miles of a paved road. A tunnel was placed under the highway when the latter was built, to permit working the limestone, most of which can be handled by gravity.

No analysis is available, but the material is claimed to be of good grade, ranging from coarsely crystalline white and bluish to a compact fine-grained marble. Some has been used by Judson Iron Works (Laizure, C. McK 25, p. 43).

Marble Peak deposit is in sec. 22, T. 20 S., R. 3 E., about 3 miles from Anderson Landing on the coast. The peak is 3966 feet high. Several smaller deposits flank it on the west and south. None of them have been developed.

Monterey Lime Company worked deposits of limestone on Bixby Creek in sec. 16, T. 18 S., R. 1 E., about 3 miles from the coast. Lime production began in 1904 with two continuous kilns and in 1905 a third kiln was added. Work was suspended in 1910. Where fresh, the limestone is white and crystalline, with grayish-blue streaks, but much of it is shattered.

Nelson Creek deposits are along the creek of that name, about 20 miles northeast of San Miguel and 3 to 4 miles west of Parkfield. The limestone outcrops are on granite along the west side of the San Andreas fault and both rocks have been brecciated and recemented. There is no record of any work having been done here.

8—74191

Patriquin marble deposit is in sec. 6. T. 23 S., R. 14 E., about 18 miles northeast of the railroad. The marble is reported to be white. It has never been developed.

Pacific Carrara Marble Company was organized before 1880 to work a deposit of white marble reported near Carmel Bay. There is no published record to indicate that production was ever made.

Unnamed Deposits in Jamesburg Quadrangle. Nearly two-thirds of the area of this quadrangle, as mapped by William M. Fiedler (44), is occupied by rocks of the Sur series, which are so rich in limestone in the region to the west. Here, however, only a few deposits have been mapped. Most are in mountainous country devoid of roads. The area as a whole is probably too remote to be considered as a possible commercial source of limestone. Known deposits are located in sec. 34, T. 17 S., R. 3 E.; secs. 17, 18, 20, T. 18 S., R. 4 E.; secs. 17, 20, T. 19 S., R. 3. E. (three separate small deposits).

Pico Blanco deposit is on the mountain of that name (elevation 3710 feet) in sec. 36, T. 18 S., R. 1 E., and extends north into section 25 as well as south into secs. 1 and 2, T. 19 S., R. 1 E. It is 5 miles east of Point Sur. According to Trask (26), it is the largest of the deposits in the Point Sur quadrangle, being "more than 1000 feet in thickness, but it thins rapidly in either direction."

The topography is rough and mountainous and the nearest road is about 2½ miles distant. There is said to be a landing on the coast north of Big Sur and about 5 miles from the deposit. The old Koch Ranch covers section 36. So far as known, the deposit is undeveloped.

Nevada County

Small quantities of lime were made in Nevada County in early days, but there has been no recorded production. The few limestone occurrences are probably Carboniferous.

Bear River marble has been mentioned as an "apparent extension of large bodies of marble" on the Placer County side of the river. Where the river traverses the metasedimentary rocks 2 miles west of Colfax, it has exposed some bodies of dark-gray to black limestone and marble. The only development has been on the Placer County side in sec. 4, T. 14 N., R. 9 E., M. D., where some dark-gray marble was produced and used in early days in San Francisco.

Greenhorn River lime kiln was operated many years ago on a small limestone body in sec. 2, T. 15 N., R. 9 E., M. D., about 2½ miles north of the junction of Greenhorn and Bear River.

Lime Kiln Ranch in secs. 4 and 5, T. 14 N., R. 8 E., M. D., about 10 miles south of Grass Valley, was the site of an early-day lime kiln and some old reports give the impression that a substantial deposit of limestone furnished the stone for it. This ranch was visited and the caretaker pointed out the site from which lime for the old kiln was taken. The only limestone to be seen is a meager amount of "float." A sample of this gave the following analysis:

	Percent
Insoluble	3.17
Fe_2O_3 and Al_2O_3	0.31
$CaCO_3$	94.96
$MgCO_3$	1.52

Lindgren and Turner (95) in the Smartsville folio indicate two very small occurrences of limestone here, at the terminations of two narrow strips of Carboniferous rocks which are embedded in amphibolite.

On *South Fork Yuba River,* 2½ miles south of North Bloomfield, a lens of marble in the Delhi (Carboniferous) formation drew some attention in 1894, and claims were located and held for 10 years or more by a group of mining men who took the name of South Yuba Marble Company. No commercial production resulted.

The walls of the river canyon are steep near the deposit, which outcrops over a vertical range of 300 feet or more. The marble is dark mottled to black. An old, unimproved road ends about 1 mile south of the river and 1000 feet above it.

Orange County

Orange County is covered mostly by geologically young sedimentary formations, with some older rocks in the eastern part. There has been little production of limestone, and none has been recorded in recent years. In the eighties, when the erection of portland cement plants was first being urged in this state, two of the soft limestone deposits in this county were mentioned as possible sources of material. These were on Rancho Canada de Los Alisos, and near San Juan Capistrano.

Capistrano deposit is in sec. 31, T. 7 S., R. 7 W., S. B., 1 mile northeast of San Juan Capistrano. It is said to have been used by the padres in building the San Juan Capistrano Mission. It is in an area mapped as upper Miocene.

El Toro deposit is on the old William L. Moulton Ranch 3½ miles south of El Toro. A crushing plant was operated on the deposit in 1923 (Tucker 25b, p. 68) and crushed limestone was sold locally as a soil corrective and fertilizer, but there has not been any recorded production since. The deposit is of good size and is soft fossiliferous limestone in an area shown on the state geologic map as upper Miocene. Forty years ago it was tested for making portland cement with clay found nearby, and was said to be satisfactory. At that time an analysis was reported to show 96 percent $CaCO_3$, 2½ percent SiO_2, 1 percent Al_2O_3 and 0.5 percent Fe_2O_3. It is believed that the average run of the deposit would show less $CaCO_3$ and more of the other ingredients as these soft limestones along the coast generally carry some clay.

Ladd Canyon deposit is in secs. 3 and 4, T. 5 S., R. 7 W., and sec. 33, T. 4 S., R. 7 W., S. B. It is about 15 miles by road east of Orange to the mining camp of Silverado. From near there, an old dirt road runs 3 to 4 miles along Ladd Canyon to the above sections where 10 mining claims were located over 20 years ago. The limestone in this region was investigated by Harold W. Fairbanks (93a, pp. 115, 116) in 1891-92 and he reported gathering from it fossil specimens which were pronounced

Carboniferous in age by the National Museum. The limestone is gray to black, not crystalline, and occurs in bunches, the largest reported by Fairbanks being 100 feet thick; others claim thicker deposits. The deposits extend toward the summit of the Santa Ana Mountains at elevations of 2200 to 2900 feet.

The following analysis of the limestone was made by F. W. Huber, University of California, over 20 years ago.

	Percent
SiO_2	1.34
CSaO	51.45
Fe_2O_3 and Al_2O_3	1.95
MgO	1.86
Ignition loss (CO_2 and H_2O)	43.08
Undetermined	0.32

So far as known, the deposits are undeveloped.

Placer County

The line of the Central Pacific Railroad (now the Ogden Route, Southern Pacific Company) was built in the early sixties and traverses nearly the entire width of Placer County from west to east. San Francisco was the metropolis of the state then, and lime was in great demand there for building, but transportation from nearby deposits was poor. Many small deposits of high-calcium limestone were found within a few miles of the railroad near Auburn, Clipper Gap, Applegate, and Colfax and with cheap rail and water transportation to San Francisco it was natural that these should be opened and equipped with lime kilns. This activity continued into the first decade after 1900, when Portland cement began to displace both granite and brick. No lime kilns have been operated in the county since 1910, and the last recorded limestone production was in 1916.

The formations in which the limestone deposits occur in this county were originally mapped by the U. S. Geological Survey as ''Carboniferous'' under the local name of Calaveras formation in the lower, western section and Cape Horn, Clipper Gap, and Delhi farther east. These names cover hard siliceous slate, phthanite, quartzite, mica schist, and limestone altered to marble, and also possibly in part by silicification to phthanite. The place of these formations in the geologic column was determined by meager fossil evidence found in the limestone at only one or two places. On the new state geologic map these formations are classed as ''Carboniferous, Mississippian.''

In western Placer County, as near Auburn and Clipper Gap, there are remnants of the old Cretaceous peneplain, on which are limited exposures of these rocks, including small bodies of limestone, all planed down by erosion to an approximate level. From Auburn east and northeast, extend the succession of deep canyons carved by American River and its tributaries. On the sides of these trenches are a number of limestone bodies which have been so stripped by erosion as to indicate that while their outcrops are small, they extend to vertical depths of several hundred feet. The first type, exposed on the old peneplain, would have to be worked through shafts. Those exposed on the sides of the stream canyons can be worked in open quarries and ''glory holes.''

Bear River Marble (formerly *Holmes Lime & Cement Company*). The Bear River deposit in W½ of lot 2 of NW¼ sec. 4, T. 14 N., R. 9 E., M.D. is now assessed to Santa Cruz Title Company, Santa Cruz, California. It has been idle for a long time. It is 3½ miles by road west of Colfax.

This was one of the earliest known marble deposits in the state, having been found in 1866. It is a dark gray stone with jet black as well as white veining, and takes a high polish. It was used in considerable quantity in San Francisco for interior work, notably in the old U. S. Mint and Bank of California buildings. Later two kilns were built and lime was burned, but there has been no production for over 30 years. A face 400 feet long was worked. It is on the south bank of Bear River and a tramway 1000 feet long was used to raise stone out of the canyon to the road.

Burton (Petterson) Deposit. This deposit is assessed to A. J. and Mattie F. Burton, R.F.D. Box 208, Auburn. It is in S½ sec. 3, T. 12 N., R. 8 E., M.D., just outside the city limits of Auburn and 1½ miles northwest by paved road from Railroad Street station on the west-bound line of the Southern Pacific Railroad.

This is a small deposit of high-calcium limestone which was worked in the early mining days when lime was made in a pot kiln nearby. The limestone was excavated as deeply as natural drainage would permit over an area 150 by 250 feet and the old quarry site is now traversed by a small stream forming a marshy area which would have to be drained before any work could be done. Part of the deposit is also probably concealed by soil so its full size could only be determined by stripping and drilling. It is a light gray, fine-to-medium-grained crystalline stone of firm texture.

The following analysis was made by Abbot A. Hanks, Inc., of a sample taken in November 1943.

Analysis of limestone from Burton deposit, by Abbot A. Hanks

	Percent
Insoluble	1.06
Ferric and aluminic oxides	0.97
Calcium carbonate	96.3
Magnesium carbonate	1.51
	99.84

Cowell Deposit. Assessed to Henry Cowell Lime & Cement Company, 2 Market Street, San Francisco. This deposit is 2½ miles by good road northwest of Bowman, on the Southern Pacific Railroad. The deposit lies in a meadow traversed by a branch of Dry Creek, and has been eroded to the level of the surrounding land, and is in large part soil-covered. A shallow quarry with an area 90 by 90 feet and not over 6 feet deep was opened years ago and limestone was burned in an old kiln nearby. At a distance of 475 feet S. 20° W. from this pit, limestone is exposed in the creek-bed for 63 feet and there is another small exposure in the stream-bed 63 feet north. There are no other rock outcrops in this meadow which contains possibly 40 acres. It is probable that most of the deposit is concealed by soil and some work would be needed to determine its full extent.

The limestone is dark gray and rather soft on the surface and apparently of good grade. Sinking would be required to open the deposit any farther.

Analysis of limestone from Cowell deposit, by Abbot A. Hanks, Inc.

	Percent
Insoluble	0.60
Ferric and aluminic oxides	0.99
Calcium carbonate	97.30
Magnesium carbonate	1.09

De Witt Limestone. Assessed to Mrs. Eleanor De Witt, 1931 C Street, Sacramento, this small deposit in sec. 30, T. 13 N., R. 9 E., M.D., is about 1½ miles south of Clipper Gap, a station on the Southern Pacific Railroad. Possibly a quarter of a mile of new road would be needed for hauling.

Limestone outcrops for a length of 250 feet and has a width varying from 50 to 100 feet. It is a dark gray, compact stone possibly similar in chemical analysis to that at the nearby "Lime Rock" deposit of Pacific Portland Cement Company. A small tonnage of limestone was quarried and burned here in an old stone kiln now in ruins. There are sufficient backs to permit mining a small tonnage in an open quarry as the limestone is on a slope.

Analysis of limestone from DeWitt deposit, by Abbot A. Hanks, Inc.

	Percent
Insoluble	2.79
Ferric and aluminic oxides	0.60
Calcium carbonate	94.80
Magnesium carbonate	1.69

Hotaling Deposit. There is a small deposit of white saccharoidal marble at the Hotaling iron mine, in sec. 15, T. 13 N., R. 8 E., M.D., 3½ miles west of Clipper Gap. This was used at the iron smelter operated on the mine in the eighties, and some of it was shipped to San Francisco for making carbonated water. According to an old analysis, it is nearly pure calcium carbonate.

Jumbo No. 1 Lode & Mill Site. Patented claims in secs. 5 and 6, T. 15 N. R. 11 E., M.D., are in the deep canyon of North Fork of American River on a limestone deposit first located by Sullivan and Linder. They sold it in 1931 to California Lime Association, a California corporation, formed for the avowed purpose of using the limestone from this deposit especially for making carbon dioxide. A large amount of stock was sold but the property was never operated.

Dan Sullivan, one of the original locators, states the deposit is 300 feet wide at the river and stands 300 feet high. The river at this point is 2000 feet vertically below the railroad and 1½ miles south of it. A steep road from Towle passes about a mile away.

Matthews deposit is in secs. 22 and 27, T. 16 N. R 13 E., M.D., 5½ miles or more by trail south of Cisco on the ridge between Granite Canyon and North Fork of American River near their confluence, at an elevation of 4000 feet. Vic Matthews reports that analyses of samples indicate the limestone is of good quality. Due to its location, there is little likelihood of it being exploited.

Muegge Deposit. Theodore C. Muegge, 450 Sutter Street, San Francisco, is the owner. It is in S½ sec. 29, T. 13 N., R. 9 E., M.D., on the south side of North Fork dam, 8 miles by road from Auburn.

The limestone is 225 feet wide at the water's edge but the outcrop is exposed for only a short distance up the slope to the south and backs are negligible.

Pacific Portland Cement Company, 417 Montgomery Street, San Francisco, own over 800 acres of land in sections 20, 21, 29, 30 and 31, T. 13 N., R. 9 E., M.D., on which are several deposits of limestone. Much of this land once belonged to Pacific Lime and Plaster Company, and a number of lime kilns have been operated in years past, but all of them have long been idle.

Lime Rock deposit is near the line between sections 29 and 30 but probably in SE¼ sec. 30, T. 13 N., R. 9 E., 2.15 miles by old road on an easy grade from Clipper Gap station on the Southern Pacific Railroad. It is a prominent outcrop on the steep slope on the north side of the North Fork debris dam. The quarry opened here years ago is from 60 to 120 feet long from north to south and 140 feet wide from east to west. Work started in 1905 and limestone is believed to have been shipped to Benicia, but there are also the remains of a lime kiln nearby. (The last recorded lime production in the county was in 1910). The remaining part of the outcrop rises 55 feet above the quarry floor, with a thickness of 50 feet. The extension northward is limited, but the steep face of limestone extends vertically at least 500 feet down the south slope toward the dam.

It is believed that the limestone in several of the deposits belonging to the company in the vicinity is similar in character, and a sample was taken across a width of 50 feet at this old quarry level, to get an idea of their quality. Analysis of this was reported as follows by Abbot A. Hanks, Inc.

	Percent
Insoluble	0.46
Ferric oxide and aluminic oxide	0.63
Calcium carbonate	98.5
Magnesium carbonate	0.40
	99.99

This limestone is dark gray, some being very fine grained. It weathers only a shade lighter than the color of the fresh stone. Like all other similar deposits, it is a fetid limestone. This is reported to be one of the few limestone deposits of the region that has yielded any fossils. If it maintains the same cross-section to 500 feet in depth, the deposit should contain 700,000 tons.

Another deposit under the same ownership is 4.2 miles by road south of Applegate station on the Southern Pacific Railroad. It is in W½ sec. 21 T. 13 N., R. 9 E., and has been partly eroded away by the North Fork of American River, with the remaining parts separated by the North Fork debris dam, so that the part east of the dam is not accessible from Applegate, but may be reached from the Auburn-Forest Hill road. By that road it is about 10 miles from railroad.

The old private road to the western part of deposit, which connects with the county road to Applegate, is in fair condition. It rises 825 feet

in $2\frac{1}{2}$ miles. On this side, the limestone shows a width of 300 feet at the old lime kiln (1000 feet elevation) and has backs of about 400 feet above the level of the dam. Only a small amount of the stone has been quarried, although it appears to be of good quality. There is a larger tonnage on the east side of the dam, and this is said to have been extensively prospected and sampled.

About 0.1 mile east, on the west side of dam, there is an outcrop of limestone 80 feet wide but of small surface area. At Long Point, about on the north line of section 21, is a cherty limestone outcrop.

No attempt to estimate the total tonnage was made but the amount of high-grade limestone on the west side of dam and accessible from the road mentioned would be of the order of a million tons, and the amount east of dam is greater.

The north end of the large limestone deposit which was so productive at the Mountain Quarries in El Dorado County, extends into Placer County. The Middle Fork of American River has eroded this part of the deposit so that no such favorable conditions exist as were found on the El Dorado County side, although there may be a very substantial tonnage below the river level. This part of the deposit extends for about three-eighths of a mile from the river bed to a place on the steep canyon slope only a little above the present Auburn-Forest Hill road. Total backs above the river are about 300 feet, but the road would prevent working all of it. It is 5 miles by road from Auburn (Railroad Street) station.

The road traverses limestone for a diagonal distance of 228 feet, but the actual width of limestone underground is probably about 160 feet. It was possible to sample a continuous width of 110 feet. This is dark gray, medium-grained, compact and fairly tough limestone, containing enough organic matter to give a faint fetid odor when hammered. The following analysis was reported by Abbot A. Hanks for this sample:

	Percent
Insoluble	0.79
Fe_2O_3 and Al_2O_3	0.59
$CaCO_3$	97.44
$MgCO_3$	0.29

Spreckels limestone deposit is assessed to C. F. and Nora C. Brunckhorst, Applegate. This was patented as Excelsior Mining and Milling Claim, 25.66 acres in secs. 8 and 9, T. 13 N., R. 9 E., M.D., 1 mile from Applegate station and alongside the Southern Pacific Railroad.

Like several other small but accessible limestone deposits in this county, this one was worked in early days and lime was produced in a kiln on the property. Spreckels Sugar Company purchased the claim and surrounding land. They drilled the deposit and worked it for a year ending in October 1916. Since then it has been idle.

The limestone is below the surface level. Drilling indicates an irregular deposit, the thickness of good limestone varying in different holes from 17 to 106 feet. An estimate based on drilling indicates 424,000 tons of limestone to a depth of 100 feet. It is fine-grained, bluish-gray and reported to be of good quality though no analysis is available.

Sullivan and McCormick claim is an unpatented location made by Dan Sullivan and McCormick, Alta, on the north end of the same deposit which is partially covered by the Jumbo patent. The limestone is claimed

to be of good grade but is undeveloped. It lies less than a mile south of Gorge on the Southern Pacific Railroad but is 1500 feet below the tracks and is said to be 1000 feet below the nearest road which runs to Towle, 3 miles distant. Sullivan states the deposit is 200 feet wide.

Plumas County

Although there are many limestone deposits in Plumas County, the local population is small and the possibility of marketing the stone nearby is therefore limited. The principal outlet is over the Western Pacific Railroad and the deposits that offer the best possibilities of future utilization are those near the rail line. Freight rates would of course have to be placed low enough to permit competition with producers in other counties.

The railroad follows the course of the canyon of the North Fork of Feather River, and from Big Bar in Butte County to the vicinity of Belden, the canyon is carved entirely in granite with no limestone deposits. From there eastward there are several bodies of limestone of very good grade, either on or near the railroad. South of Granite Basin and near Hartman Bar on the Middle Fork of Feather River, in a rough and remote region, are numerous bodies of limestone and marble.

The limestones of the region occur in a number of different geologic formations, ranging from the Silurian Montgomery formation to the lower or middle Jurassic Thompson limestone. By far the larger part, much of it in remote and relatively inaccessible parts of the county, is in the Carboniferous Mississippian meta-sediments, which have been mapped as the Calaveras formation because of stratigraphic similarities and lack of fossil evidence. These beds have undergone so much compression and folding that the limestone members have been crystallized and in many places changed to marble, and are generally the remaining portions of lens-shaped deposits that have been tilted to a nearly vertical position and more or less eroded.

In composition they range from high-calcium to highly magnesian limestone, with as much as 20 percent MgO. The latter weather to a dirty light-gray color and the U. S. Geological Survey was unable to find any fossils in a large number of samples (Turner, H. W. 96, p. 629). The limestones containing fossils which led to their classification as Calaveras weather a dark bluish-gray, and this color is characteristic of them throughout the western foothill section of the Sierra Nevada.

Farther north in the central part of the county, J. S. Diller (08) studied the geology and described limestones of various ages. The most interesting of these is the Hosselkus limestone, taking its name from the Hosselkus Ranch in Genesee Valley. The largest body of this limestone extends from the SW$\frac{1}{4}$ sec. 3, T. 25 N., R. 11 E., M.D., (a mile northeast of Genesee) through secs. 28, 33, and 34, T. 26 N., R. 11 E., with a continuous exposure 2 miles long. This is upper Triassic, dark blue when fresh and weathering a light gray. According to Diller, its greatest thickness in this region is 140 feet. It lies at 4500 feet elevation and is about 15 miles from the railroad, with a road extending almost to the deposit from the railroad 1$\frac{1}{2}$ miles north of Crescent Mills. No analyses are available for the Hosselkus limestone in this locality, but under Shasta County, in which the Triassic limestone is much more abundant, several analyses are given in this report.

The Montgomery (Silurian) limestone outcrops in small bodies at intervals along the western border of the Grizzly formation, beginning 1 mile south of Taylorsville. None of these have been worked and several are in rough, inaccessible parts of the Grizzly Mountains.

In the Shoofly (Carboniferous, Calaveras) formation Diller mapped a lens of limestone half a mile long in sec. 14, T. 25 N., R. 9 E., and three smaller outcrops nearby. These are said to be as much as 50 feet thick in places. They are all less than a mile from the railroad and county road. In the Downieville quadrangle, south of the area mapped by Diller, such deposits are mapped as Carboniferous, Calaveras and all are shown as Mississippian on the state geologic map. The Shoofly limestone has not been developed and no analysis is available.

The Thompson (Jurassic) formation contains some narrow bodies of limestone, principally in secs. 23, 24, 25, 26, and 35, T. 26 N., R. 10 E. Some lime is said to have been made near the north end, probably for limited local use. Some years ago, claims were located on some of these outcrops, which were said to offer promise, but there is no record of production in recent years. The thickness of the beds ranges from 10 to 40 feet according to Diller.

Limestone Point deposit is a prominent deposit on a hill just north of the Middle Fork of Feather River, $2\frac{3}{4}$ miles west of Nelson Bar bridge.

It is too remote to be of interest except geologically. It is a magnesian limestone, according to the following analysis by the U. S. Geological Survey (Turner, H. W. 96, p. 630) of a type differing from the ordinary Carboniferous high-calcium limestones of the Sierra Nevada.

Partial analysis, limestone from Limestone Point

	Percent
Silica	2.29
Lime	30.19
Magnesia	9.99

On the south side of the river there is a smaller lens, offset east.

Marble Cone is in secs. 6 and 7, T. 22 N., R. 8 E., on the Middle Fork of Feather River. In an extremely inaccessible region reached only by trail, the deposit was located before 1900 as the possible site of a marble quarry when it was thought a railroad might be built through the river canyon. There are two large bodies of marble, one on the south side of the river and one mostly on the north side. The latter bears the name now.

Pyramidial Lime Deposit. It is in secs. 6, 7, and 8, T. 25 N., R. 8 E., near Virgilia on the Western Pacific Railroad. Of the 960 acres once held, 480 acres has been patented. As originally located, the Pyramidal placer mine extended from Cherry Peak in the southeast corner of T. 26 N., R. 7 E., for nearly $3\frac{1}{2}$ miles southeastward across secs. 6, 7, 8, and 17, T. 25 N., R. 8 E., covering a series of lenses of limestone in the Cedar formation (Triassic marine meta-sediments). The outcrops range from 2500 feet to about 4800 feet elevation, going from Virgilia northwestward. The width of limestone on Cherry Hill is reported to be 800 feet, but in places calcareous shale is interbedded with the limestone; however, wide layers free from shale can be found.

A tunnel 275 feet long has been run in the deposit and some lime was made in an old-style kiln, the last recorded production being 350 barrels in 1927.

The following analyses are from a report by Edw. H. Scott.

Composite of 11 samples, Pyramidal lime deposit

	Percent
Water	3.4
Iron oxide Fe_2O_3	0.4
Alumina Al_2O_3	1.6
Magnesia MgO	0.3
Silica SiO_2	6.0
Lime CaO	49.1
Carbon dioxide CO_2	39.1

The following is from a width of 150 feet of limestone free from shale, lying next to the hanging wall:

	Percent
Fe_2O_3,Al_2O_3	1.6
MgO	0.3
SiO_2	2.9
CaO	53.3
CO_2	41.9

There are shale and slate layers nearby that are claimed to be suitable to mix with the limestone to make Portland cement, and parts of the deposit where the shale and limestone layers are interbedded are said to approximate a ''Belgian natural Portland cement''.

Silver White placer claim is in S½ SW¼ SE¼ sec. 1, and NW¼ NE¼ sec. 12, T. 23 N., R. 11 E., M.D., 3 miles northeast of Sloat on the Western Pacific Railroad. More than 20 years ago, Plumas Lime & Rock Company was formed to work the deposit, but did not reach production. The deposit was examined by E. G. Manasse, president, and C. B. Kinney, chief chemist, of The Sawyer Tanning Company. They estimated the body of limestone to be about 750 feet long and 200 feet wide, so that it should contain 1,250,000 tons to a depth of 100 feet if it maintains these dimensions. A spur track from the main line is said to be feasible on a good grade.

The following analyses are reported to have been made by C. B. Kinney from samples he took from the deposit in 1920:

	(Gray) *No. 1*	*(Light gray)* *No. 2*	*(White)* *No. 3*
Loss on ignition	43.56%	43.66%	41.94%
Silica	0.91	1.06	3.31
Iron and alumina (Fe_2O_3 and Al_2O_3)	0.63	0.57	1.47
Calcium oxide	53.87	54.37	52.69
Magnesium oxide	0.50	trace	trace

Western Star travertine deposit is in secs. 3 and 9, T. 25 N., R. 9 E., on a county road and only a few hundred feet from the railroad. The claims have been held for years by Western Star Gold Mining Company. The travertine covers several acres, and depths ranging from 8 to 20 feet can be observed (Averill, C. V. 37, p. 142). The travertine is banded and may have some value for ornamental purposes. In 1937, S. Gallegos had an option on the claims and furnished the following analyses, of

which No. 1 and No. 2 are said to have been made by Abbot A. Hanks, Inc., and No. 3 by Henry Cowell Lime & Cement Company.

	No. 1	*No. 2*	*No. 3*
Silica	0.07%	0.07%	0.26%
Iron oxide	0.14	0.33	0.20
Alumina	0.05		0.06
Lime	54.72	55.20	54.94
Magnesia	0.36	0.50	0.62
Ignition loss	44.42	44.05	43.84
Calculated			
Calcium carbonate	97.65	98.52	98.10
Magnesium carbonate	0.75	----	1.30

Riverside County

About two-thirds of the area of Riverside County is in the arid Colorado Desert where there are numerous large outcrops of pre-Cambrian and pre-Cretaceous rocks. These probably contain some large deposits of limestone, but the region lacks the railroad facilities enjoyed by San Bernardino County, and the deposits are so remote from transportation that they have received little attention.

The principal production has come from the deposits at Crestmore in the western part of the county and from smaller deposits as far east as Whitewater and Palm Springs, as well as in the region of Hemet and San Jacinto, where railroad service is available. In general, these deposits are Paleozoic or older (but analyses of the limestone suggest Carboniferous), and have been intruded by or are enfolded in Jurassic granitic rocks.

The Crestmore limestone deposits have been widely known and studied for many years by mineralogists because of the great variety of minerals occurring there in the contact zones between the limestone and the intrusive rocks. The late Professor Arthur S. Eakle called attention to this rich mineral field and described some of the rare minerals in 1914. In a late article, A. O. Woodford (43) has listed and described 112 named minerals and 14 unnamed from these deposits. His paper is also of interest for its detailed study of the geology of the deposits.

Aside from the quarrying of limestone for making cement at Crestmore, there has been only one other producer of limestone in the county for several years, and he reported no output in 1946.

Blythe cement claims nos. 1 to 5 are 160-acre association placer claims located in 1928-29, at distances of 3 to 3½ miles west of Chandler Well and 4 to 4½ miles north of the Arlington manganese mine, in secs. 26 and 35, T. 3 S., R. 19 E., S. B. The 8 locators were W. V. and G. M. Neuman, B. F. and J. E. Rockhold, Martha B. and E. E. Schellenger, Mrs. Lulla Stearns, and D. R. Hall, Blythe. The nearest railroad points are on the Atchison, Topeka and Santa Fe Railroad, 10 miles northeast or 14 miles southeast at Inca. No details are available, although the limestone is said to be of good grade. The claims were undeveloped so far as known.

Carbonate Blanket group of four association placer claims were located from 2 to 3½ miles south of U. S. Gypsum Company's Gyp well, and within 3 or 4 miles northwest of Midland on the Atchison, Topeka and Santa Fe Railroad. For locators names, see Blythe cement claims. No production nor activity has been reported.

Eden Hot Springs deposit is in sec. 23, T. 3 S., R. 2 W., S. B., just east of the springs. It is white, coarsely crystalline and high-grade limestone. It is assessed to Thos. D. and Eliza McTavish, Route 1, Box 82, Camarillo, California, and is about 4 miles by road southwest of Beaumont. No recent activity has been noted.

Guiberson limestone deposit is on 160 acres of patented land in E½ NE¼ and NE¼ SE¼ sec. 22 and SW¼ sec. 23, T. 3 S., R. 3 E., S. B., about 1 mile south of Whitewater Station on the Southern Pacific Railroad. Owner, S. A. Guiberson, Jr., 1000 Forrest Avenue, Dallas, Texas. The limestone is enclosed by and intruded by the granitic rocks of San Jacinto Mountain, on whose northern flank it lies. As mentioned by Tucker (45, p. 172), it was drilled by the Metropolitan Water District of Southern California and the greatest thickness of limestone reported was 110 feet. Some prospect cuts and adits were run nearly 20 years ago, but no production has been reported. The following analysis of the limestone is from Tucker (29a).

	Percent
SiO_2	0.74
Al_2O_3	0.004
Fe_2O_3	0.008
CaO	53.29
MgO	2.39

Harris limestone deposit is shown on a map accompanying Tucker's report (45) as lying in sec. 9, T. 7 S., R. 5 E., S. B., but has not been described. It is on the Pines to Palms highway at an elevation of 4,000 to 4,500 feet.

Hubbard limestone deposit is in sec. 23, T. 4 S., R. 1 W., S. B., 4 miles northwest of San Jacinto and on a steep slope just north of the road between Soboba Hot Springs and Gilman Hot Springs. Many years ago it is said to have been worked by Snowflake Lime Company, who had a lime kiln below it near the road. It is a white crystalline limestone, one of a series of outcrops striking northwest, and is believed to be of good grade. The quarry, which was a small one, is about 1000 feet above the road. There has been no recent activity. William F. Rohland and Mary Heinsen, Gilman Hot Springs Post Office, were listed as owners in 1945.

Lamb Canyon deposit is in sec. 36, T. 3 S., R. 2 W., S. B., 3 miles by road northwest of Gilman Hot Springs. This is one of the small deposits worked many years ago. The limestone was burned in a kiln which stood near the main road a mile south of the quarry. No work has been done here in many years.

Magstone Products. Howard Small, Route 5, Box 50, Riverside, has been a producer of limestone from 1938-45, but did not report production in 1946. The quarry is on Arlington Avenue, in the city of Riverside. It is on 17½ acres owned by Loren Creed, Riverside. In 1945, Tucker and Sampson (45) described the work as a side-hill cut 100 feet long by 20 feet high on a deposit of gray and white limestone, the size of which could not be judged because of overburden. The stone was hauled to a plant at 331 Main Street, Riverside, where it was crushed and screened for sale as poultry grit and as limestone flour for use in poultry feeds. The plant had a capacity of 8 tons a day and employed one to three men.

Mammoth 7 limestone claim contains 80 acres within 1 mile of Southern Pacific Railroad, Palm Springs Station. The owner is Louis Steck, 443 North 7th Street, Colton, California.

The deposit extends from the desert level up a mountain side, rising 600 feet in elevation with little or no overburden. The owner built half a mile of road and shipped out a few carloads of limestone several years ago to Los Angeles, and made several exploratory cuts. Some aplite dikes occur.

The following analysis was made by Smith, Emery & Company, Los Angeles:

	Percent
SiO_2	0.96
Fe_2O_3	0.07
Al_2O_3	0.25
CaO	53.35
MgO	1.75
CO_2	43.60
Purity as $CaCO_3$	95.1
	99.98

Moore limestone deposit is in Bautiste Canyon about 12 miles southeast of Hemet. The limestone is reported by Sampson (32, p. 7) to outcrop in the canyon for 2 miles and is about 30 feet wide, with granite walls. It is finely crystalline and white to blue. A quarry 50 feet long by 20 feet high was opened about 20 years ago and some production was made, but there has been no work recently. Edward J. and Ruth S. Moore were owners in 1945.

Novell limestone deposit is in sec. 26, T. 3 S., R. 3 E., S. B., 2 miles south of Whitewater on the Southern Pacific Railroad. It is blue to gray, coarsely crystalline limestone striking N. 40° W. and is reported to extend southeast on the strike for 2500 feet. No production has been reported.

About 1 mile southwest of Pinyon Flat and probably in secs. 5 and 6, T. 7 S., R. 5 E., S. B., about 28 miles by road southwest of Indio, there is a prominent outcrop of limestone striking N. 45° W. and dipping 50° NE. It is at an elevation of 4000 feet. According to Waring (Merrill 19, p. 550) it overlies granite unconformably and is overlain by coarse granitic gneiss and has a "surface exposure about ½ mile wide." This may be the Big Hill deposit (Tucker 45).

Riverside Cement Company, with offices at 200 Bush Street, San Francisco, and 621 South Hope Street, Los Angeles, owns a portland cement plant and 850 acres of land containing limestone deposits at Crestmore 5 miles northwest of Riverside, as well as the plant and land formerly owned by Golden Gate Portland Cement Company, already mentioned under San Bernardino County. The Riverside plant has a capacity of 10,000 barrels daily and uses the dry process. It has been in operation since 1909. The cement plant and the limestone quarrying and later mining operations have been described by Merrill (19), and Tucker (29a, 45). The underground mining of limestone by block caving, started in 1927, attracted attention of mining engineers and has been described in detail by Robotham (34) and in Technical Publication 1766, American Institute of Mining & Metallurgical Engineers, by R. H. Wightman, the present mine superintendent. The geology and mineralogy of the main limestone deposit and the associated intrusive rocks have been of great

interest because of the variety of minerals found, and this has led to publication of several articles, the latest of which is by A. O. Woodford (43).

Before the erection of the cement plant, the main deposit was worked in a small way to make lime and marble by Sky Blue Marble & Onyx Company. Some of the marble was used in Riverside, Los Angeles, and San Francisco prior to 1906, and in that year two lime kilns were in operation. An analysis of the Riverside blue marble from this deposit was quoted in Bulletin 38 of the State Mining Bureau (Aubury 06) as follows:

	Percent
Lime (CaO)	55.85
Equivalent to $CaCO_3$	99.73
MgO	0.30
Iron	trace

This remarkably pure limestone capped an isolated butte of granodiorite of fairly coarse granitic structure, which was composed of orthoclase, plagioclase, hornblende, biotite and quartz. Instead of clay, this granodiorite has been used with the limestone to make cement, and this practice was regarded as unusual when it was started. A number of other surface quarries have been worked, including those on Chino Hill, adjoining Sky Blue Hill workings on the southwest. These are all close to the cement plant, and the mine shaft is only a few hundred feet south of the latter. Another working 2 miles northwest of the plant is called Little Hill quarry, which is a large open pit, 1,000 feet in diameter at top and 125 feet deep. The deposits are essentially roof pendants, as are others described in this county, but these are distinctive because of their size. The igneous rocks forming the walls have protected them. They are roughly lens-shaped, striking north to northwest and dipping east or northeast as much as 50° to 55°.

The lower or western bed of Chino Hill limestone is white and coarsely crystalline and not as pure as part of the Sky Blue, as it contains some bands of predazzite, which carries brucite. This bed has a depth on the dip of 1200 to 1500 feet, extends 2000 feet on the strike and is said to be about 300 feet thick. The vertical five-compartment shaft sunk to work it when the open quarries had reached ground level is 350 feet deep.

Part of the limestone on Sky Blue Hill resembles the Chino limestone in color and composition, but the blue beds which gave it the name were in places 50 feet thick, occurring close to the granodiorite. This limestone is remarkably high grade, nearly pure calcite. The three quarries on Sky Blue Hill, at different levels, have a combined length north to south of about 1500 and a combined width east to west of about 1200 feet. The total area of surface operations is roughly 2000 by 3000 feet.

San Jacinto Rock Products Company produced limestone in 1927-28 from a deposit on the southwest side of Babtiste Canyon, 12 miles southeast of Hemet. The limestone is 30 feet wide, strikes northwest and dips southwest, with granite walls. A quarry 30 feet high by 100 feet long was opened. The limestone was hauled to a grinding plant at San Jacinto and ground for use in poultry food or grits.

Southern Pacific Land Company owns a limestone deposit near the railroad in sec. 23, T. 3 S., R. 3 E., S. B., less than 1 mile south of Whitewater station. It is coarsely crystalline, white, and reported to carry 98 percent $CaCO_3$. The reported thickness of 100 to 200 feet includes some

layers of diorite and of mica schist. No production has been reported from this deposit.

Whitecap Limestone No. 1 and No. 2 claims were located in 1928 by the same persons who located the Carbonate and Blythe cement claims. These claims are 160-acre placer locations in the SW$\frac{1}{4}$ sec. 29, W$\frac{1}{2}$ sec. 31, and in sec. 32, T. 3 S., R. 21 E., S. B., 1 to 2 miles north of Midland on the Atchison Topeka and Santa Fe Railroad. No work nor production has been reported from these claims, which are said to be on a deposit of high-calcium limestone.

San Benito County

Limestone and dolomite are plentiful in this county and considerable lime was burned many years ago. Lately the limestone produced has been used for making portland cement. Dolomite production started in 1915 and has been carried on intermittently. The limestone and dolomite are the oldest rocks of the region. They are found along the Gabilan Range from San Juan Bautista southeastward to the vicinity of The Pinnacles, an air-line distance of 24 miles. They are older than the pre-Franciscan Santa Lucia granite. The dolomite has been found on the lower slopes in those places where erosion has exposed it, and it can be seen to rest directly on decomposed granitic rock, or to be intruded by dikes and sills of such rock. Several of the dolomite deposits were described in 1915 (Bradley, W. W. 19, pp. 633-636). The composition and physical character, including crystal form, show it to be a true dolomite but it may grade into dolomitic limestone within a short distance or show silicification near granitic contacts.

The removal of the railroad between Hollister and Tres Pinos has increased the length of the truck haul from many of the limestone and dolomite deposits. Hollister is the only feasible outlet for deposits south of that town.

Limestone

Archer Lime Company was organized many years ago to work a limestone deposit in secs. 13 and 23, T. 14 S., R. 5 E., about 17 miles by road south of Hollister. The deposit has never been worked. It is now assessed to Amy R. McPhail, Hollister.

Barbee Ranch deposit, see Pacific Portland Cement Company.

Cienega Lime Company, see Henry Cowell Lime and Cement Company.

Crowe Ranch deposits are 9 to 10 miles south of Hollister via Bird Creek and Cienega Valley road. Owner is Miss Cassie Crowe, R.F.D., Hollister. The extensive holdings include limestone rights on 1800 acres and dolomite deposits in addition to the dolomite sold in 1943 to the Permanente Corporation (see under *Dolomite*). The limestone includes a deposit formerly owned by American Smelting and Refining Company. The land was all part of Rancho Cienega del Gabilan, an old land grant never subdivided into sections. The deposits are 1$\frac{1}{2}$ miles west of the main road at elevations of from 800 to 2200 feet on the northeast slopes of the Gabilan Range.

The limestone has not been developed nor prospected enough to give any definite idea of tonnage, which is large. The following analyses were made by Howard Harris. Results are so high as to suggest that selected specimens were taken.

Reported analyses of Crowe limestone

Sample No.	SiO_2	Fe_2O_3+ Al_2O_3	CaO	MgO	CO_2	$CaCO_3$ (approx.)
1	0.30	0.25	54.76	0.79	43.69	97.7
2	0.25	0.30	53.18	2.13	44.13	95.
3	0.25	0.10	55.30	0.43	43.90	98.7
4	0.30	0.35	55.50	0.36	43.96	99.1
5	0.35	0.35	55.45	0.54	44.10	99.0
6	0.2	0.25	55.50	0.35	43.25	99.1
7	0.1	0.20	37.99	14.83	46.77	68.0

George Melendey Ranch in W½ sec. 27, T. 15 S., R. 7 E., contains a large part of a deposit of Gabilan limestone which extends along the course of the San Andreas fault close to state highway 119 between Willow Creek school and Jungle Inn. The deposit is 24 miles southeast of Hollister by road, and at an elevation ranging from 1000 to 1200 feet.

The road crosses the southern end of the deposit, but the largest section extends for a mile northwest nearly parallel to the road on the west side. There it rises to a height of 200 feet and has a maximum width of possibly 500 feet, but is only 75 feet wide where the road crosses; it terminates at the south in a block 50 feet wide. It is grayish-blue to white marble and is distinctly a recemented fault breccia. So far as known, no work has been done upon it.

A sample taken across a width of 75 feet near the south end gave the following result:

Analysis by Abbott A. Hanks, Ins. June 1946

	Percent
Insoluble	4.59
Ferric and aluminic oxides	0.26
Calcium carbonate	92.08
Magnesium carbonate	2.99
Total	99.92

This deposit extends also across the NE¼ sec. 28 and into the S½ sec. 21, T. 15 S., R. 7 E.

Hamilton (Scott Ranch) deposit is on the slope of Mount Hanlon (locally called also Mount Harlan) about 17 miles south of Hollister by the Bird Creek and Cienega Valley road, in sec. 23, T. 14 S., R. 5 E. (approximate). A. E. Hamilton and associates, Box 621, Hollister, have been interested in this deposit for some time. From 1930-32, Hamilton produced and sold lime and limestone. He claims to have here a large deposit of good grade. The following analysis was reported made by Smith, Emery and Company August 12, 1936:

	Percent
SiO_2	0.14
Al_2O_3	0.10
Fe_2O_3	0.02
CaO	54.19
MgO	0.84
Loss on ignition	44.34
Purity as $CaCO_3$	96.72

Harlan limestone deposit in secs. 23, 24, T. 14 S., R. 5 E., about 17 miles south of Hollister, was worked 40 years ago by U. G. Harlan who made lime in a pot kiln. Nothing has been done here in late years.

Henry Cowell Lime & Cement Company, 2 Market Street, San Francisco, owns 1045 acres in secs. 28, 29, 30 and 32, T. 14 S., R. 6 E., and nearby in T. 14 S., R. 5 E., on and near Thompson Creek. The old kilns were in NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 30 near the creek at an elevation of 1000 feet. The Cienega Lime Company worked the deposit in the eighties and nineties, and operated four small kilns. No limestone or lime has been produced since about 1900. Formerly the product was hauled to Tres Pinos, but since the removal of the railroad tracks the nearest railroad point is Hollister, 17 miles away.

The limestone, ranging from white to gray and from fine to coarse crystalline in structure, lies directly on decomposed granitic rock which is exposed near the creek level. The limestone outcrops at intervals on the hillside above the creek over a vertical range of several hundred feet.

McPhail deposits in secs. 13 and 23, T. 14 S., R. 5 E., were formerly listed under Archer Lime Company. The 245 acres of land is now assessed to Amy R. McPhail, Hollister. The largest outcrop is on a tract of 81 acres in section 23, but no figures of possible tonnage are available. D. McPhail, late secretary for Archer Lime Company, claimed several analyses indicated 96 percent $CaCO_3$ and from $2\frac{1}{4}$ to 4 percent $MgCO_3$. Hollister, on the railroad, is about 17 miles to the north.

Old Mission Portland Cement Company holdings passed in 1927 by merger to *Pacific Portland Cement Company,* 417 Montgomery Street, San Francisco. The cement plant at San Juan Bautista has a capacity of 2500 barrells a day. After being shut down since 1930, it was put in operation in 1941, but closed again during 1943. It was again reopened early in 1947.

The limestone holdings in San Benito County include those on the Barbee Ranch, 696 acres, about half a mile from the cement plant; 85 acres on Underwood Ranch, $2\frac{1}{2}$ miles from plant; Flint Ranch, 512 acres, 4 miles from the plant; and mineral rights on 8750 acres on Gabilan Peak, about 9 miles from the plant, but this latter land is mostly in Monterey County. There are two rail connections, a broad-gauge railroad 7.94 miles long called the California Central Railroad which connects the cement plant with the Southern Pacific main line at Chittenden, and a narrow-gauge line which was formerly used to take limestone to the plant from the deposits in San Juan Canyon.

The Flint Ranch deposit, a principal source of supply, lies along the tops of the steep hills above San Juan Canyon. In the Gabilan Peak deposits, the limestone shows all degrees of silicification. At several places near the top of the peak, deposits of white, high-grade barite have been found in the limestone and proved large enough to repay mining. The Gabilan limestone is older than the granitic rock and has been changed to highly crystalline marble. The color ranges from dark blue to nearly pure white. At these upper elevations much of the stone is high-calcium limestone carrying perhaps 96 percent $CaCO_3$ according to William F. Jones (11, p. 58). He quoted the following analyses which were furnished by San Juan Portland Cement Company, predecessor to Old Mission Portland Cement Company:

	1 Percent	2 Percent
Moisture	0.10	0.10
Silica and insol. res.	2.62	1.00
$CaCO_3$	96.23	96.62
Fe_2O_3	0.30	0.05
Al_2O_3	0.40	trace
MgO	0.24	2.19
Organic matter	----	0.10

In 1913, Old Mission Portland Cement Company erected four continuous-system vertical lime kilns of 75 barrels daily capacity each at the cement plant site. These were never put in commission.

San Benito Lime Company operated a 50-ton lime kiln 40 years ago on a deposit adjoining the McPhail land in sec. 23, T. 14 S., R. 5 E. Recently the 219.62 acres has been assessed to Marie Mayries, P. O. Box 1444, San Francisco. The composition of limestone in this section has been mentioned under *Hamilton* and *McPhail.*

Underwood deposit, see Pacific Portland Cement Company.

Dolomite

Probably the oldest rock in the county is the dolomite which occurs as part of the undifferentiated Gabilan limestone. These beds are older than the pre-Franciscan Santa Lucia granite, on which they lie.

Dolomite production began near Vineyard School in this county in 1915. It has been carried on intermittently by one or two producers who sold from 2500 tons to 18,000 tons a year. The use of dolomite during the last war for making magnesium and in the steel business stimulated the search for deposits in the region, and considerable prospecting and sampling of deposits in the county was done, although most of the war-time production in northern California was made from deposits in the western foothills of the Gabilan Range in adjoining Monterey County.

The roof pendants of limestone and dolomite are not shown on the San Benito County portion of the state geologic map (Jenkins, O. P. 38) and so far as known to the writer have not been studied in detail. The dolomite deposits mentioned here are in the extreme northern part of Gonzales quadrangle and the adjacent part of Hollister quadrangle. They occur at intervals from Monterey County east and southeast to the vicinity of Cienega School, so far as noted by the writer, who limited his inspection to that region because of the distance from the railroad. The deposits are along or near the San Andreas fault zone and have a vertical range of 800 to 2200 feet.

Some of the deposits described in 1915 by the writer (Bradley, W. W. 19, pp. 633-636) have passed into other hands and have lost their identities in the more extended prospecting which has resulted in the proving of larger deposits. Only one operator was active at time of visit.

When used in steel furnaces, a dolomite with less than 1 percent silica is preferred. For use in making magnesium, a minimum of 21 percent MgO was sought.

Cienega del Gabilan Rancho was a Spanish or Mexican land grant antedating American occupancy of California, and has not been covered by the public survey, so that locations of deposits cannot be given by

section. The deposits mentioned here are within the original boundaries of this grant 8 to 11 miles south of Hollister.

Crowe Ranch deposit is owned by Miss Cassie Crowe, R. F. D., Hollister. This land is part of the original grant called Rancho Cienega del Gabilan and lies west of the Bird Creek road 7½ to 9 miles south of Hollister, rising into the Gabilan Range west of Vineyard School. In 1943, a dolomite deposit on this land was prospected by and was sold to Permanente Metals Corporation.

In addition the remaining Crowe holdings cover limestone rights on 1800 acres including a deposit formerly owned by American Smelting & Refining Company and a deposit of "sandy" dolomite estimated by the owner to contain 300,000 tons.

A. E. Hamilton, Box 621, Hollister, has been producing dolomite since 1937 from the deposit formerly worked by A. A. Haskins on land assessed to Anglo-California National Bank about three-quarters of a mile by road southwest of Vineyard and 10 miles southwest of Hollister. Hamilton's lease covers 78.86 acres. Dolomite has been worked in open quarries. Much of it comes from the deposit broken rather fine so that as much as 50 percent is screened before sending the balance through a No. 2 Hammer Mill. There is a 4- by 8-foot pan feeder and 4- by 5-foot scalper screen. For steel-plant use sizes through ¾-inch or preferably ⅝-inch and retained on 6-mesh are desired.

There is generally an overburden of 3 feet or less of soil on the deposit. The dolomite is pure white and high grade. Both to the east and west it merges into silicified dolomitic limestone, and the total length of marketable dolomite is uncertain, but is possibly 500 feet. The following is an analysis made by Smith, Emery & Company, San Francisco:

	Percent
Insoluble (SiO_2)	0.17
Iron oxide (Fe_2O_3)	0.11
Alumina (Al_2O_3)	0.36
Manganese	0.006
Titanium	none
Lime (CaO)	31.00
Magnesia (MgO)	21.23
Loss on ignition (CO_2)	47.30

Martin Ranch deposit is 8 miles south of Hollister, on land adjoining the Permanente deposit on the northwest. Work started on the deposit in 1916 and continued for a number of years, but the property was inactive at time of last visit. The following analysis was made in 1916 by Abbot A. Hanks, Inc.

	Percent
$CaCO_3$	54.54
$MgCO_3$	42.78
Fe_2O_3 and Al_2O_3	0.80
SiO_2	1.00

O'Hara Ranch deposit was assessed in 1943 to Thomas J. and James V. O'Hara and Frances P. O'Connor, P.O. Box 281, Vallejo, and was under option to A. E. Hamilton, whose rights were reported in April 1944 to have been transferred to Westvaco Chlorine Products Corporation, Newark, California.

Dolomite was first produced in 1915 from this 400-acre holding by Baldi and Rothschild under the name San Benito Quarries Company. It is 11 miles south of Hollister and 1.8 miles south of Vineyard by road. When visited in December 1943 much new prospecting had been done, which indicated a large deposit. Cuts made by tractor and bulldozer exposed dolomite over a length of 1500 feet in a S. 65° W. direction, and a quarry face nearly 350 feet east of the east end of the bulldozer cut indicated that much additional length. Another cut nearly at right angles to the above exposed a width of about 630 feet in a S. 28° E. direction. The dolomite in this direction appeared to terminate at a gully which perhaps marks a fault trace near the summit of the ridge, across which the long dimension of deposit extends toward the Hamilton deposit. The quarry face, 185 feet wide, exposed dolomite for 120 feet N. 15° W. and 40 to 45 feet high. At the south end, the quarry shows the dolomite resting on a thoroughly rotted rock which in turn has been pierced by dikes of granitic rock, also thoroughly decomposed.

According to Hamilton, 5 drill holes were drilled 118 feet and a total of 8,000,000 tons of dolomite was indicated. This would be the tonnage present in a block 600 feet wide by 1500 feet long and 100 feet in depth, with no allowance for waste in quarrying, or loss due to variation in the chemical composition. Both are likely to be important factors in working a dolomite deposit in this region, as was found in the Permanente operation near Natividad.

Detailed analyses were not available at the time of visit for samples from the drill-holes. In the early work near the surface Baldi and Rothschild claimed 21.55 percent MgO and at the Hamilton workings a quarter to half a mile west 21.23 percent MgO was claimed. Near the underlying intrusive the amount of silica increases; probably the analyses of all deposits in the area are quite similar.

Permanente deposit is on 237 acres owned by The Permanente Metals Corporation, Permanente, California. The land adjoins the Crowe and Martin holdings, is about 2 miles west of Vineyard School and 10 miles by road south of Hollister.

The dolomite was prospected in 1943 by numerous drill holes. Some churn-drill holes as much as 100 feet deep are said to have bottomed in the deposit. Most of the work, however, was done with jackhammers, about 1000 holes having been drilled. The deposit is close to the San Andreas fault zone and rises to an elevation of 2200 feet on the east slope of the Gabilan Mountains.

The prospecting is reported to have indicated a deposit of several million tons of which over 1,000,000 tons in the upper part, farthest from the intrusive is high in MgO and ranges from 0.35 to 0.75 percent SiO_2 with Fe_2O_3 and Al_2O_3 running 1 percent or less. Near the intrusive at the base of deposit the silica content increases to 3 percent or more in places. The owners required over 20 percent MgO in dolomite being used at the time to make magnesium, and a large part of the deposit is claimed to exceed this. No production has been made from the property.

San Bernardino County

San Bernardino County contains many large high-calcium limestone deposits, sufficient to serve the needs of Los Angeles and the surrounding thickly settled regions for an indefinitely long time and at a much greater

rate of production than so far reached. In 1945, three cement plants (of a total of six in southern California) operated in the southwestern section of the county and three companies produced 121,183 tons of "industrial" limestone, including that used for making lime in two plants. Production expanded in 1946.

There are numerous deposits within moderate trucking distance of railroads and within reasonable rail distance of the Los Angeles metropolitan area, and many others in reserve at greater distance. The county has a long mileage of good desert roads which serve as feeders to the two paved state highways and the two transcontinental railroads which cross it from east to west. San Bernardino is the largest county in the United States, containing over 20,000 square miles, of which 18,500 square miles are classed as desert. Most of the residents live in the fertile southwest section, within 70 miles of Los Angeles.

The work of W. B. Tucker, District Mining Engineer, and Reid J. Sampson, Assistant Mining Engineer of the Division of Mines at Los Angeles has been drawn upon freely. Messrs. Tucker and Sampson have been most helpful and co-operative in supplying details of recent developments.

Adelanto deposit is on 320 acres of patented land in sec. 2, T. 6 N., R. 6 W., S. B., 6 miles northwest of Adelanto at an elevation of 3,000 feet. It was sold late in 1946 to Southwestern Portland Cement Company, Victorville.

This is a deposit of blue-gray to white, fine to medium crystalline limestone striking N. 20° W. across the Black Marble and Dee patented placer claims for half a mile. It is at the southeast end of the Shadow Mountains, and is shown on the state geologic map (Jenkins, O.P. 38) as "undivided Paleozoic metasediments." Such rocks are described in a nearby area by William J. Miller (44, p. 98) as late Paleozoic (Oro Grande metasediments). The principal members of the series are the limestone and nearly white to light-greenish-gray quartzite. Thin bands of the quartzite and of biotitic quartz schist may be found interbedded with the limestone, which is generally a high-calcium stone. On this property the beds are said to be over 1000 feet thick and to rise 400 feet above the desert plain. According to Tucker and Sampson (43, p. 516) this property is estimated to contain over 50,000,000 tons of limestone. The following is an analysis of the stone by Smith Emery & Co.

	Percent
SiO_2	3.36
Al_2O_3 and Fe_2O_3	0.74
CaO	52.50
MgO	0.36
Ignition loss	41.52
$CaCO_3$	94.00

Arlington and Black Hawk groups containing 175 claims located originally for gold in secs. 5, 8, 9, 16, 17 and vicinity, T. 3 N., R. 2 E., S.B., were (Tucker, W.B. 43, p. 516) owned by James Hay, 8517 West Third Street, Los Angeles. The claims are on the northeast slope of the San Bernardino Mountains, up to 6700 feet elevation. Gold occurs in a slightly silicified and iron-stained limestone breccia which lies between a massive limestone hanging wall and granite footwall.

For details regarding limestone in this region, see *Furnace Limestone.*

Baker limestone deposit comprises 160 acres in sec. 26 (?), T. 14 N., R. 8 E., S.B., 1 mile west of Baker; owner is J. W. Neblett, Riverside, California. This deposit forms a rounded hill which rises 400 feet and is 2 miles in length along its north-south axis. The limestone is crystalline, blue to gray in color and is approximately 98 percent calcium carbonate.

Baxter and Ballardie limestone deposits (White Marble group and other claims) are in sec. 12, T. 11 N., R. 6 E., S.B., half a mile to a mile north of Baxter on the Union Pacific Railroad, and there are rail facilities near the quarry face. This property was most actively worked 30 years ago and much limestone was shipped to beet-sugar refineries. The property contained 118.62 acres in four claims called White Marble nos. 1, 2, and 3 and Evening Star, in the southern half of the section. The work was done principally on White Marble No. 1 claim in the south half of the southwest quarter of the section. Mrs. Louis D. Rasor, owner, Los Angeles.

The limestone outcrops for 4500 feet, striking northeast, with a width of 400 to 800 feet and rises 600 feet above the desert. The larger part is salmon or flesh colored, with some beds of blue and white. In 1914-16, about 60 men were employed and about 65,000 tons of limestone was shipped annually. No production has been reported for nearly 20 years. The limestone is folded and has been invaded by dikes. It varies in texture from coarsely crystalline to dense, close-grained marble, there being a large deposit of white marble on the No. 2 claim. The following analysis is from H. C. Cloudman 19, p. 873.

Analysis of limestone from White Marble No. 1 claim

	Percent
SiO_2	2.24
Fe_2O_3, Al_2O_3	0.53
$CaCO_3$	97.93
$MgCO_3$	0.54
$CaSO_4$	0.15
H_2O	0.21
Total	101.60

Big Pine deposit is just north of Swarthout Valley in the northwest corner of T. 3 N., R. 7 W., S. B., near Wrightwood and the Los Angeles County line, and about 12 miles by the Lone Pine Canyon road from Cajon on the Santa Fe Railroad. The valley follows the trace of San Andreas fault and has an elevation of 6000 feet; the limestone extends several hundred feet higher on the north.

In 1930, Big Pine Mining Corporation (?) had three 160-acre association placer claims, covering partly exposed limestone outcrops said to be 200 feet or more thick and traceable for a mile. There is no record of any work by the above company except shallow prospect cuts made about 1930. The limestone is white and is reported to carry 85 to 95 percent $CaCO_3$. It strikes northwest and dips 45° SW. The older formation on the north side of the fault is Archean metamorphic. (See Lamb Bros. and Douglas Lime Products).

Cajon limestone deposit is on 420 acres in sec. 32, T. 3 N., R. 6 W., S. B., in Lone Pine Canyon 4 miles west of Cajon Station on Atchison Topeka and Santa Fe Railroad by road. Cajon Lime Products started

three quarries in the limestone about 1924 and erected a lime kiln of 125 tons daily capacity in sec. 27. Work was carried on until 1927, after which there is no record of production. In January 1945, Douglas Lime Products Company, L. C. Douglas, president and manager, leased the limestone deposits and lime plant. Mrs. Lorin Foreman, Los Angeles, is the owner. The lessee did considerable work during 1945 and planned to produce lime and ground limestone of 40-, 80-, and 200-mesh for poultry and other industrial uses.

California Portland Cement Company, E. E. Duque, president; L. E. Bancroft, secretary; W. C. Hanna, chief chemist and mechanical engineer; E. I. Hendrickson, superintendent, 601 West Fifth Street, Los Angeles, owns and operates the Colton cement plant and quarry, situated in secs. 19 and 30, T. 1 S., R. 4 W., about a mile west of Colton.

The plant is at the foot of the south slope of Slover Mountain and the quarry is in the south side of this mountain, which is approximately a mile long, half a mile wide at its base, and 500 feet high. With the exception of a little shale, the whole mass is crystalline limestone suitable for the manufacture of cement. The shale is not waste as it also is utilized in the mix. The present quarry face is about 3500 feet long and something over 300 feet in height. The rock is broken by churn-drill holes from the top and coyote holes in the face. One shot a few years ago brought down more than a million tons.

The rock is loaded into 30-ton trucks by two 3½-yard electric shovels, and hauled to a 66- by 84-inch jaw crusher, the feed floor of which is on the quarry floor. The 10-inch product goes to no. 9 gyratory, then no. 18 gyratory, by means of elevators, to vibrating screen; plus ¾-inch goes to hammer mill, discharge from which, together with undersize from screen, goes to storage bins, thence to driers, to twelve 250-ton proportioning bins, where it is held until analyses of samples show that the proper mix has been attained. From bins it goes to battery of 6- by 22-foot tube mills, one 7½- by 26-foot tube mill and Allis-Chalmers preliminator mill, where it is all ground to minus 200 mesh. These machines are equipped with air separators. From raw grinding section it goes to silos having storage capacity of 16,000 tons, thence by Fuller-Kenyon pumps to 8 kilns (seven 200 feet in length, and one 236 feet long), thence to cooling rotary tubes to belt, to clinker pile, where gypsum is added; it is reclaimed by traveling crane and the grinding is finished by tube mills. The plant has a capacity of 50,000 sacks of cement per day, and is the largest in southern California. The company has been making cement on practically this same site since 1891. Two hundred and fifty men are employed.

Chalmers dolomite deposit is on patented sec. 29, T. 6 N., R. 13 E., S.B., 640 acres, 6 miles east of Amboy and 1 mile north of paved highway U. S. 66 A. F. Becker, 4278 Beverly Boulevard, Los Angeles, was the owner in 1943 (Tucker, W. B. 43, pp. 517-518).

The dolomite occurs as roof pendants on a number of hills forming the southeast tip of the Bristol Mountains. The elevation ranges from 1000 to 1400 feet. This dolomite has been classified as "undifferentiated Palaezoic" and the amount available was estimated by Tucker and Sampson as 1,000,000 tons. They quoted the following analysis made by Smith Emery & Company, Los Angeles:

	Percent
Acid insoluble	1.00
Alumnia (Al_2O_3)	0.36
Iron oxide (Fe_2O_3)	0.20
Calcium oxide (CaO)	33.68
Magnesium oxide (MgO)	18.23
Loss on ignition	46.50
	99.97

Chubbuck limestone and dolomite deposits are in two extensive holdings, described below for convenience under two titles, Chubbuck Lime Company deposits and Chubbuck reserve deposits. The former have been in production for many years. The Chubbuck reserve deposits have been the subject of both geological and engineering investigations that have yielded much interesting information, but so far have been worked only for test purposes.

Chubbuck Lime Company deposits were first worked from 1925-30 by Charles I. Chubbuck, and since then by Chubbuck Lime Company with Charles I. Chubbuck, president and general manager and Mrs. A. S. Chubbuck, secretary. The main office is at 5000 Worth Street, Los Angeles. The land holdings include three patented association placer claims of 160 acres each in secs. 10, 11, 15, 22, T. 3 N., R. 16 E., S. B.; the E½ and SW¼ sec. 16, and all of sec. 21, T. 3 N., R. 16 E., S. B. The land in section 16 was patented in March 1947 to Chas. I. Chubbuck by the State of California. The deposits are 1 to 2 miles southwest of Chubbuck, a station on the Parker-Phoenix branch of the Atchison Topeka and Santa Fe Railway about 16 miles southeast of Cadiz.

The deposits are roof pendants of high-calcium coarsely crystalline limestone on a series of parallel ridges striking north-northwest with one ridge lying southwest of the others having a deposit of dolomite. Four quarries have been operated. Work has been principally on High Lime Ridge which is about 1½ miles long by 1 mile wide rising to an elevation of 1500 feet, about 500 feet above the surrounding desert. The deposits are at the north end of the Iron Mountains.

The limestone and dolomite here are in the Essex series of metamorphosed sediments with minor amounts of altered igneous material. The Essex series is said to be the oldest unit of the Archean complex, and includes: (1) a basal quartz-feldspar-biotite gneiss about 1500 feet thick; (2) the Chubbuck marble member, 500 to 600 feet thick, consisting of marble, quartzite, and schist; and (3), a thick upper unit of quartz-feldspar-biotite gneiss (Hazzard, J. C. 37).

In the quarries opened by 1943, limestone had been worked to a depth of 30 feet, widths of 150 to 200 feet and lengths of 500 to 600 feet. Tucker and Sampson (43, pp. 519-521) described the operations as follows:

The limestone is being quarried from No. 4 quarry. The broken material is loaded by gas-driven shovel ⅝-yard bucket, into 5-ton dump truck and hauled to ore bin with a capacity of 150 tons. Material is dumped onto railroad iron grizzly spaced to 8 inches; rock from bin loaded into side-dump cars, capacity 2½ tons per car; hauled in train of 5 cars by Plymouth gas-driven motor to crushing plant where dumped into ore bin; from bin to Kennedy gyratory crusher, crushed to 1½-inch size; crushed rock elevated by bucket elevator to top of screening plant equipped with 5 Cottrell shaking screens, making the following products: 1½-inch, $\frac{5}{16}$-inch, ⅛-inch, 16-mesh and 40-mesh. These products go to separate bins, above concrete

tunnel, there being 4 bins on one side and 2 bins on the other side. The sized products from bins are loaded into steel side-dump cars and hauled over narrow gauge railroad in trains of 4 to 6 cars, capacity 2½ tons of rock per car, by Milwaukee gas-driven locomotive to plant at Chubbuck, a distance of 1 mile. The $\frac{5}{16}$-inch to 1½-inch product to lime kiln plant. The other sizes are hauled by train to trestle to elevator and shipped.

The $\frac{5}{16}$-inch to ⅛-inch products are ground in pebble mill, then to air separator and the 80 mesh and 200 mesh products are sacked for shipment to Los Angeles and San Francisco.

The crushing and screening plant is driven by one 1-cylinder, 50-horsepower Fairbanks-Morse semi-diesel engine and one 35-horsepower semi-diesel Fairbanks-Morse engine drives Sullivan compressor for operation of air drills at quarries. The crushing and screening plant has a capacity of 20 tons per 8-hour shift.

Lime kiln plant: The $\frac{5}{16}$-inch to 1½-inch product from screening plant is hauled by ore train over narrow gauge railroad to hopper to 24-inch belt conveyor to 50-ton storage bin. From bin it is elevated by bucket elevator to circular steel storage bin, capacity 50 tons. From steel storage bin, material is fed by automatic feeder to rotary kiln (50 feet in length by 5 feet in diameter); heated to 2000° F.; the calcined lime from kiln to steel hopper; elevated by bucket elevator to revolving screen and screened to ¼-inch size. The minus ¼-inch size produced to circular steel bin, capacity 40 tons; the plus ¼-inch material to 3 circular steel ore bins, each having a capacity of 40 tons. From the three bins, the lime is drawn by screw conveyor to 20-ton capacity bin, then by automatic feeder to 14-foot by 5-foot pebble mill, driven by 75-horsepower motor. The product from pebble mill then goes to elevator to separator; the oversize returned to pebble mill. The calcined lime is ground to minus 200 mesh for processed lime. The 200 mesh product is elevated to storage bin from which it goes to bag packing machines and is sacked for shipment. The oversize lime products are fines and pebble lime.

Limestone products plant: The $\frac{5}{16}$-inch and ⅛-inch product to 5 feet in diameter by 14 feet long pebble mill, driven by 60-horsepower motor; the ground product from pebble mill to separator; two products produced are 80 mesh and minus 200 mesh; the oversize from separator returned to ball mill.

Power plant at Chubbuck for operating kiln and pebble mills consists of one 120-horsepower, 4-cylinder, Fairbanks-Morse full diesel engine, direct connected with 75 K.V.A. generator and one 110-horsepower Fairbanks-Morse 2-cylinder, diesel engine, direct connected with 75-horsepower K.V.A. generator and one 60-horsepower horizontal Fairbanks-Morse full diesel engine. The 110-horsepower diesel engine operates kiln, screen, and pebble mill. When both pebble mills are under operation, the 120-horsepower diesel engine is operated. Water for camp and plant is secured in tank cars from the Santa Fe Railroad Company's wells at Cadiz.

The lime products produced are processed lime and pebble lime. Limestone products are 40 mesh limestone, 80 mesh limestone, 200 mesh for whiting, chicken grits and foundry rock 1½-inch to 2½-inch sizes.

Analysis of crude limestone

	Percent
Silica (SiO_2)	0.20
Alumina (Al_2O_3)	0.30
Calcium oxide (CaO)	56.00
Magnesium oxide (MgO)	None
Loss in ignition	43.30

Twenty-four men are employed at quarry and plant.

Chubbuck reserve limestone and dolomite deposits are in N½ sec. 20, NW¼ sec. 21, SE¼ and E½SW¼ sec. 17, T. 6 N., R. 14 E., S.B., in the Marble Mountains 7½ miles west of north of Cadiz, a station on the Atchison, Topeka and Santa Fe Railroad. The deposits are controlled by Chubbuck Lime Company, Charles I. Chubbuck, president and general manager and Mrs. A. S. Chubbuck, secretary, with the main office at 5000 Worth Street, Los Angeles. The Kaiser Company, Incorporated, did some work on the property in 1943 and 1944, but it is idle at present.

C. W. Clark (21) has mentioned Carboniferous limestone of an estimated thickness of 635 feet as occurring in the Bristol Mountains "5 miles due north of Cadiz." This note probably refers to the above

deposit but the name Bristol Mountains is in error, as that name is usually applied to a range farther west, lying north of Amboy. He made no reference to the dolomite.

In a private report made in 1943, Charles Severy has described the deposits in detail. The following quotation is from his report:

> Structurally the area is composed of a metamorphosed sedimentary section which has been folded into an overturned anticline and this in turn thrust over a meta-diorite by a reverse fault which dips approximately 50° to the north. This fault can be traced for several miles along the front of the mountains. To the west is another fault which strikes approximately N. 40° E. and separates the sedimentaries and the meta-dorite from an acid igneous rock, probably a granite. This fault dips from the vertical to 65° to the east, and to the north near the top of the limestone it assumes a 25° dip to the east. Minor zones of movement are present in the limestones.
>
> There are three metamorphosed sedimentary formations in the area: a white limestone which constitutes the main mass of the deposit, a blue limestone which occurs in two lenticular beds separated by a bed of dolomite and the main dolomite formation.
>
> The white limestone forms a ridge some 700 feet high with precipitous slopes commonly in excess of 60°. The bedding of the limestone is massive and usually obscure, but the ridge is apparently part of the leading edge of an overturned anticline whose axial plane is inclined to the north approximately 25°. Near the base of the limestone ridge to the east, the strike of the beds is approximately N. 65° E. and the dip is from vertical to 85° N., while higher on the same portion of the ridge the strike is similar, but the dip has changed to approximately 45° southerly. There are numerous zones of movement in the limestone, but as the bedding is obscure, an accurate measurement of the displacement along these faults cannot be made, however, it is believed that the displacement in all cases is small.
>
> The material is a finely crystalline rock that has local variations from a cryptocrystalline texture to a medium crystalline one. The individual grains show well developed cleavage faces and are interlocked. The color of the limestone varies from a pure milk white to a dark brown and includes clear, translucent varieties as well as mottled red, yellow and brown types. On weathered surfaces the limestone is commonly a medium grey or buff color, and occasionally has a sugary, friable texture. Often minute subhedral to euhedral crystals of magnetite are present in the limestone.
>
> In some beds of the white limestone free silica is found in the form of small nodules and lenses, usually around two to three inches in size, but occasionally extending up to three feet or so in length and one foot in thickness. These lenses and nodules of silica weather a dark brown and are secondary in origin.
>
> Small basic dikes having approximately the composition of a hornblende andesite occur through both the limestone and the dolomite. They are dark green to black in color, aphanitic in texture, and can be traced on the surface for distances ranging up to 75 feet. Their width is from 18 inches to three feet, and in general they appear to be regular in both strike and dip. They are not common enough as seen on the surface, to constitute a serious waste ratio in the limestone as they are scarce and can easily be sorted.
>
> The blue limestones are found in two beds paralleling the face of the white limestone, apparently conformable with it, and separated from each other by an intermediate bed of dolomite. Both beds vary in width along the strike, pinching and swelling and occasionally disappearing entirely, which lends a lenticular aspect to the beds. The southerly blue limestone bed is the thicker and more persistent of the two beds, being from 10 to 50 feet wide, while the northern bed is seldom more than 15 feet in thickness and, toward the west, is commonly discontinuous while the southern bed merely thins rapidly. Both beds are composed of a fine crystalline rock having a blue-grey color probably due to minute amounts of carbonaceous material now metamorphosed to graphite. The chemical composition is similar to that of the white limestone (see analyses). A few basic dikes are present and some free silica is visible as small lenses.
>
> The intermediate dolomite bed lies between the two blue limestone beds and has a varying thickness from approximately 30 feet to 110 feet, pinching and swelling to some extent, but in general thickening steadily toward the west until it is separated from the main dolomite only by a narrow five to ten foot thickness of blue limestone and from the white limestone by occasional narrow lenses of the northern blue limestone.

This dolomite is finely crystalline and for the most part is a milky white in color on a fresh surface, weathering to a characteristic reddish brown which makes the dolomite in this area readily distinguishable in the field from the adjacent formations.

On the west, the contact between the middle dolomite and the limestone would appear to be a gradational one as the rock has the analysis of a magnesium limestone (10% MgO).

The main dolomite formation, which lies to the south of the southern blue limestone, occupies three ridges forming salients from the main mass of the mountains. There is no visible bedding in the dolomite, but it is assumed to be comformable with the blue limestones as there are no indications to the contrary where the contact is exposed.

The dolomite varies from a cryptocrystalline, dense type in which no individual grains are megascopically visible to a finely crystalline variety. Both are white in color with occasional brownish mottling. A few euhedral crystals of hematite, pseudomorphs after magnetite, are found. The bed becomes narrower near the center of the deposit due to the folding of the strata combined with the position of the underlying fault.

The dolomite rests on what has been termed in the field as a meta-diorite, and is separated from it by a reverse or thrust fault dipping approximately 50° toward the north. Along the contact there has been hydrothermal action as shown by the presence of abundant epidote and some garnet. Locally along the contact the diorite contains a large percentage of biotite, lending a schistose structure to the rock. There are acidic phases in the diorite having the composition of a granite and occasionally of an alaskite, but they are comparatively minor.

On the west side the meta-sediments are terminated by a fault which brings an acid intrusive having the composition of a granite or a quartz monzonite against them. Along this contact there are local areas of abundant epidote and small deposits of iron, replacements of the limestone, while some 1500 feet further west and to the south lies the Iron Hat ore deposit.

Chemical Composition

Following are the average analyses of the various types of limestones and dolomites found on the deposit:

	SiO_2	CaO	MgO	Al_2O_3	Fe
White limestone	1.58	53.54	.31	.39	.18
Blue limestone	2.31	52.32	.82	--	.17
Main dolomite	1.56	31.22	20.23	.73	.66
Intermediate dolomite	2.26	31.99	20.03	--	--

The decrepitation tests show a wide variation, from 2 to 68.8. It is possible that this high decrepitation index was due to the weathered condition of the sample. An estimated average decrepitation for the limestone is between 15 and 20. The individual analyses will be found at the end of the report.

The Kaiser Company, Inc. prospected both the dolomite and limestone. A quarry bench was opened in the dolomite on the toe of the east ridge and dolomite was hauled in 5-ton trucks a distance of 7 miles to a railroad spur a quarter of a mile west of Cadiz for shipment to the company's steel plant at Fontana. The average analysis of dolomite resulting from averaging the figures quoted for a number of carloads, indicated 1.65 percent SiO_2, 30.9 percent CaO and 19.8 percent MgO.

The limestone prospecting consisted of an adit in white limestone, but the extent of work done was so small in comparison with the extent of deposit that no conclusion could be drawn from it, as it was started in a bed which may be a comparatively narrow stratum of Cambrian limestone or dolomite and not the main limestone member.

The property is 1½ miles long from east to west and 1 mile from north to south, and the tonnages of both limestone and dolomite in it are very large. The mining of the white limestone would be limited to certain methods because of the steep slope. R. E. Tally Jr., after an inspection, suggested the use of tunnel shots using 3- by 5-foot tunnels to be driven

70 feet into the face, then forked 150 feet each way, east and west, loaded with explosive, back-filled, and fired. He estimated that 3 such shots, 167 feet apart on the steep limestone face, would break 1,175,000 tons.

Severy estimated that the block of limestone under investigation, which is only a part of the Chubbuck holdings would yield 13,100,000 tons of white limestone and 34,800,000 tons of dolomite, not counting the two beds of blue limestone and the "intermediate dolomite" bed, as these would be wasted in the mining method proposed. As the Chubbuck property extends 4000 feet east and 800 feet or more north of the area covered by Severy's estimates, and is occupied largely by the white limestone, the estimate of 100,000,000 tons of limestone quoted by Tucker and Sampson (43) need not be considered excessive.

Water is obtainable in small quantity from wells at the old and new Chambless Service Stations, 2.4 miles and 3.2 miles distant respectively, and might be had in larger amount from well at Cadiz; or possibly other wells might be drilled. No electric power is available.

Cima limestone deposit is in secs. 12, 13, and 24, T. 15 N., R. 13 E., and sec. 7, T. 15 N., R. 14 E., 10 to 12 miles by road nearly north from Cima on the Union Pacific Railroad. Owners are James Vernon and W. R. Fory, Arlington; C. B. Worcester, Riverside; and R. F. Slaughter, San Clemente. The total area is 1380 acres in 10 placer claims at elevations ranging from 4900 to 5900 feet on a western spur at the Ivanpah Mountains. It is mapped as undifferentiated Carboniferous.

The limestone makes up a large part of the mountain, which is about 2 miles long and has a maximum width of about 1 mile. The strata of limestone range in thickness up to 300 feet. The texture varies from fine grained and compact to coarse crystalline and the color from dark slate to white. A random sample said to have been taken "from entire deposit" and analyzed by Smith Emery & Co. July 21, 1943 gave the following (Laboratory No. 237,245):

	Percent
Calcium carbonate ($CaCO_3$)	97.20
Magnesium oxide (MgO)	0.45
Calcium carbonate ($CaCO_3$)	97.20

The writer has not visited the property, but it has been mentioned by W. B. Tucker and R. J. Sampson (43, p. 521). The owners claim that estimates indicate more than 220,000,000 tons of limestone above the base or surrounding desert level. There has been no reported production, the only work being prospecting pits.

Grades on the road from the deposit to the railroad are almost entirely in favor of loaded traffic, Cima being at 4204 feet elevation, or 700 to 800 feet below the base of the deposit. There is ample space available for any plant desired, and as the country is almost uninhabited desert, no trouble would arise from dust or fumes. It should be possible to run a railroad spur track to the deposit at moderate cost. Cima is 250 miles by rail from Los Angeles.

Mescal Spring 6 miles north, and Roseberry Spring and Mexican Well 7 miles north of the deposit, as well as others toward Cima, might supply sufficient water for domestic use if a supply could not be developed near the property. The railroad also has a well at Chase, 4 miles south of Cima.

Devil's Canyon limestone deposit is in N½ sec. 5, T. 1 N., R. 4 W., S.B., 6½ miles north of San Bernardino, at an elevation of 1500 feet. San Bernardino Limestone Company, Incorporated, is the owner; Julian Bailey, president, and Cresti Waldenfelds, secretary, 1709 West 8th Street, Los Angeles.

A deposit of white crystalline limestone of good grade was worked here in 1942. After quarrying, the stone was crushed and screened in a plant having a capacity of 40 tons a day, after which it was shipped to Los Angeles where it is said to have been used in defense housing projects.

Douglas Lime Products Company. President is L. C. Douglas, Wrightwood, California. During the past 2 years this company has done considerable work on limestone deposits described elsewhere in this report. In January 1945 they began work under lease and option on the Cajon Lime Products Company's deposit and plant in secs. 27 and 32, T. 3 N., R. 6 W., S.B. In the same year, the company had a lease and option on Lamb Brothers limestone deposits in secs. 3, 4, 10, 15, and 22, T. 3 N., R. 7 W., S.B. A quarry was opened on this deposit in section 4. This quarry is 1 mile east of Wrightwood at an elevation of 5700 feet on a limestone outcrop 500 feet wide. The quarry is 200 feet wide and about 200 feet below the outcrop on top of the mountain. The limestone is reported to be white, high-calcium stone but badly shattered. This large deposit is described in greater detail, herein, with analyses, under *Lamb Brothers.*

Early in 1947, Douglas Lime Products Company leased the Mill Creek Limestone Company's deposit in secs. 15 and 22, T. 1 S., R. 1 E., S.B., on north side of Mill Creek 2 miles above Fallvale and about 23 miles east of Redlands. This deposit was worked in 1942-43 by Mill Creek Limestone Company and is described under that name.

Dunton limestone deposit comprises twenty-five 160-acre placer claims situated in Cushenberry Canyon on the north slope of the San Bernardino Mountains, between Arctic Canyon and Blackhawk Canyon, in secs. 10, 11, 12, 13, 14, 15, 16, T. 3 N., R. 1 E., S.B., 9 miles southeast of Lucerne; elevation 4500 to 5200 feet. Owners are Claire Dunton and R. B. Kincannon, Alhambra, California; under lease to the Kennedy Minerals Company, John Kennedy, president and manager, 2550 East Olympic Boulevard, Los Angeles.

A belt of Carboniferous limestone, about 2 miles in width, strikes eastward, dips 50° S., and is exposed on both sides of Cushenberry Canyon. North of Monarch Flat, a quarry face has been started on a massive bed of white, crystalline limestone. The quarry face is 150 feet in length. The broken material from quarry is loaded by steam shovel into truck and hauled to ramp, dumped over railroad grizzly into ore pocket, then loaded into 10-ton trucks and hauled to Thorne Siding for shipment to Los Angeles. They are shipping 1000 tons per month. Ten men are employed.

This work is going on west of the Arlington Mining Corporation deposits. For a fuller description of these Carboniferous deposits, see under *Furnace limestone.*

Hesperia dolomite deposit comprises five 160-acre placer claims, located on the north slope of Ord Mountain in secs. 27, 28, 33, T. 4 N., R. 3 W., S.B., 7 miles east of Hesperia, a station on the Santa Fe

Railroad; elevation 3500 to 4200 feet; owners, S. D. Greenwood, Clinton Ray and Claire Dunton, Glendale, California.

The deposit of dolomite is 700 feet thick by half a mile in width and $1\frac{1}{2}$ miles in length. The dolomite is white to brown in color. The estimated tonnage is said to be 80,000,000. Idle.

Analysis

	Percent
Calcium oxide (CaO)	32.1
Magnesium oxide (MgO)	21.7
Silica (SiO_2)	0.40
Iron (Fe_2O_3)	0.40

Hinkley dolomite deposit comprises 320 acres in the SE$\frac{1}{4}$ sec. 11 and the SW$\frac{1}{4}$ sec. 12, T. 9 N., R. 4 W., 4 miles southwest of Hinkley, a station on the Santa Fe Railroad. The owner is A. R. Mills, 9396 Second Street, Riverside, California; the property is under lease to W. C. O'Connor, 7940 Sunset Boulevard, Los Angeles; J. A. Vandergrift is consulting engineer.

The deposit forms a ridge, the axis of which trends eastward. On the north this ridge rises abruptly to some 200 feet above the valley, while the south slope is much more gradual. On the north, the granitic rock which apparently forms the footwall of the deposit, outcrops to about 50 feet above the valley, while on the south the deposit dips under the alluvium of the valley. The deposit is approximately 200 feet long by 1200 to 1500 feet wide at the base of the ridge, by 150 feet high. Except for a few narrow, discontinuous diorite dikes which strike N. 50° to 60° E., the whole mass is white to light-gray dolomite, the analysis of which is as follows:

	Percent
Silica SiO_2	3.03
Alumina Al_2O_3	0.25
Iron Fe_2O_3	trace
Lime CaO	28.93
Magnesia MgO	20.93
Ignition loss	48.86

Early in 1944 some 4 miles of road was built from the Hinkley highway to the deposit. At the terminus of this road, which is about midway of the east-west extremities of the deposit and 125 feet below the crest of the ridge on the south slope, machinery to give the following flow sheet was installed: Railroad rail grizzly, about 15-inch openings, to pocket to inclined 20-inch belt conveyor to 12- by 24-inch jaw crusher to 18-inch inclined conveyor to hopper to double deck vibrating screen; $\frac{5}{8}$-inch and $\frac{1}{8}$-inch through screen; plus $\frac{5}{8}$ by elevator to Symons impact crusher; back to screens; the minus $\frac{5}{8}$-inch plus $\frac{1}{8}$-inch by two inclined, 18-inch conveyors to 3 bins each 130 tons capacity. The plant is all-steel construction. Machines have individual motor drives. Power is supplied by 3-cylinder Fairbanks-Morse Diesel engine, direct-connected to 162 K.V.A. generator. There is also a 309-cubic-foot Chicago pneumatic compressor to supply air for the quarry.

The plant has a capacity of 50 tons per hour. The product has been shipped to Kaiser Company's steel mills at Fontana.

Jack Frost deposit, consisting of 160 acres, is in the Bristol Mountains, $6\frac{1}{2}$ miles northeast of Amboy, a station on the Santa Fe Railroad, in sec. 26, T. 6 N., R. 12 E., S.B.; owners are D. N. Smith and associates, of Los Angeles.

This deposit of crystalline limestone is approximately 3000 feet long, 1200 feet wide, and 400 feet thick. The strike is northwest, the dip 30° to 40° NE. The deposit has been intruded by a series of diorite and andesitic dikes striking N. 30° W., dipping 60° to 70° NE. Idle.

Johnson dolomite deposit is 5 miles south of Balch, a station on the Union Pacific Railroad, at 900 feet elevation. Owner is Edward Johnson, Baker, California. There are three 20-acre claims, located in 1942. Prospecting has been by open pit. Johnson reports that no production has been made and there is no equipment on the claims.

Lamb Brothers limestone deposits (Sheep Creek deposits), occur on holdings of about 1700 acres in secs. 1, 3, 4, 10, 15, and 22, T. 3 N., R. 7 W., S.B. The part in sec. 4, which has received most attention, is about 10 miles by road from a mainline railroad. John Gaarden, Blackstone Apartments, 244 South Olive Street, Los Angeles 12, and associates, are at present interested in the property. It has been examined and sampled by Dr. W. C. Bass, president, Smith Emery & Company, Los Angeles (1929); Richard K. Meade, Baltimore, Maryland (1930); and numerous analyses have been made by Research Laboratories, H. J. Warsap, Chief Chemist, Los Angeles. These reports have been drawn upon for the following details. Most of the examinations have been for the purpose of determining if the limestone is suitable for making portland cement, and if tonnage is sufficient to justify a cement plant. Tests have also been made of clay deposits in the vicinity. A spur track 9½ miles long on an easy grade would connect the main limestone deposit with the broad gauge railroad used jointly by the Union Pacific and Atchison, Topeka and Santa Fe Railway Companies through Cajon Pass. The deposits are 80 to 85 miles from Los Angeles by rail or highway.

According to W. C. Bass,

"The deposit (on sec. 4) comprises two large hills of limestone. There is little or no overburden so that the limestone is well exposed. The east hill is about 1000 feet wide by 1800 feet long and rises to a height of 500 feet. Limestone outcrops over this entire hill with the exception of a few minor intrusions. The west hill lies about 700 feet further west and is connected with the first hill by a lower 'saddle.' The east and south ends of this hill are composed of limestone. The bold outcrops indicate limestone over an area extending from the east end of the hill 900 feet north to an intrusion of igneous rock. The east base of the hill is at an elevation of 5500 feet and the lime outcrop extends up to an elevation of 5950 feet at the west contact. The igneous intrusion, probably about 200 feet wide, cuts diagonally across the north side of the hill in a direction a little north of west. It also cuts out most of the limestone from the west half of the saddle which connects the two hills. North of the intrusion is a ledge of limestone, probably 50 feet or more in thickness, which extends from the east hill as far west as the west contact of the west hill.

"The limestone is a crystalline, high-calcium stone. Much of it is pure white of a high grade which would be suited for chemical purposes.

"Average samples were taken, one over the East Hill and one over the West Hill, to represent material which would result from quarrying all the rock.

Average analyses, Lamb Bros. limestone

	East Hill Percent	*West Hill* Percent
Silica	1.70	6.00
Aluminum oxide	0.54	1.42
Iron oxide	0.26	0.38
Magnesium oxide	0.73	1.07
Calcium oxide	53.40	50.50
Loss on ignition	42.60	40.60
Total	99.23	99.97"

The Meade report gives the following average analyses of limestone from the two hills:

	Low (East) Hill Percent	*High (West) Hill* Percent
Silica	2.37	3.01
Alumina	0.45	0.68
Iron oxide	0.31	0.37
Carbonate of lime	94.53	93.51
Carbonate of magnesia	2.22	2.24

The following 14 analyses from the Meade report show the variations in different parts of the deposit:

Analyses of the limestone from Sheep Creek Canyon

Samples taken from base of High (Western) Hill

Laboratory Number	*1*	*2*	*3*	*4*	*5*
Silica	2.30	2.54	1.68	5.30	0.32
Alumina	.20	0.42	0.39	0.64	0.12
Iron oxide	.10	0.24	0.27	0.32	0.10
Carbonate of lime	94.51	93.94	95.98	91.60	97.84
Carbonate of magnesia	3.15	2.78	2.16	2.11	1.60

Samples taken from top of the Low (Eastern) Hill

Laboratory Number	*13*	*14*	*15*
Silica	2.16	1.84	2.74
Alumina	0.81	0.62	0.44
Iron oxide	0.42	0.48	0.52
Carbonate of lime	93.44	95.00	94.46
Carbonate of magnesia	2.10	2.00	1.88

Samples taken from base of High (Western) Hill

Laboratory Number	*6*	*7*	*8*
Silica	2.16	2.44	5.44
Alumina	0.80	0.66	1.10
Iron oxide	0.42	0.44	0.54
Carbonate of lime	93.44	94.42	91.75
Carbonate of magnesia	2.10	2.12	1.32

Samples taken from top of High (Western) Hill

Laboratory Number	*9*	*10*
Silica	0.70	4.30
Alumina	0.38	0.48
Iron oxide	0.20	0.24
Carbonate of lime	96.32	91.60
Carbonate of magnesia	2.40	3.28

Sample taken from top of hog back

Laboratory Number	*12*
Silica	0.10
Alumina	0.72
Iron oxide	0.36
Carbonate of lime	93.80
Carbonate of magnesia	3.04

The two reports state the limestone is suitable for making several types of portland cement, when used with the clay which occurs in upper Cajon Canyon, 20 miles from the limestone.

The property has not been drilled, so far as known, but both Bass and Meade made estimates as follows of probable tonnage of limestone in the two hills above the 5200-foot contour:

Bass estimate	50,000,000 tons
Meade estimate	46,000,000 tons

Besides the numerous analyses quoted above, many others are available indicating from 97.5 to over 99 percent $CaCO_3$. These were probably taken from selected beds which might be worked to yield a very high-calcium limestone for special uses.

Lawton deposit is on 800 acres of land in sec. 18, T. 2 N., R. 5 W., and sec. 13, T. 2 N., R. 6 W., S.B., about 1½ miles north of Keenbrook. Dolomite and silica are reported on the property also, and some work has been done on the silica, but so far as the records indicate, no limestone has been sold. In 1931 John P. Lawton, Sierra Madre, was listed as owner.

Lucky Strike deposit is on the Lake Arrowhead highway 12 miles north of San Bernardino on the southwest slope of the San Bernardino Mountains at an elevation of about 4500 feet. The deposit was exposed in the highway cut for a distance of 1000 feet and has an apparent thickness of 150 to 200 feet. The stone is white to gray crystalline limestone and said to be of good grade, but no analysis is available. It was leased in 1931, but no production is recorded (Tucker, W.B. 31, pp. 385-386).

Marble placer claim is in NW¼ sec. 13, T. 11 N., R. 6 E., S.B., adjoining on the south the White Marble No. 1 claim of Baxter and Ballardie quarry near Baxter on the Union Pacific Railroad. A railroad spur from the main line crosses the claim, which was worked between 1914 and 1928 by the Sugar Lime Rock Company, then operators of the Baxter and Ballardie quarry. The stone is similar in the two quarries.

Magnesium Giant mine contains 2 claims (about 40 acres) in sec. 33, T. 16 N., R. 11 E., S.B., in Halloran Springs mining district about 26 miles northwest of Cima on the Union Pacific Railroad. The owner is A. J. Rygh, 1409 Calumet Avenue, Los Angeles 26, California.

The deposit is in a hill rising 150 feet at an elevation of about 4400 feet. It is completely exposed and without overburden, so could be worked by open pits. There is a dirt road 3 miles long connecting with the paved highway, and electric power is 3 miles distant. No analysis of the material is available. The owner claims a large tonnage of clean, high-grade crystalline dolomite.

Mayflower claim is a lode location (20.66 acres) 8 miles north of Amboy. G. A. Childers, of 128 North Flower Street, Los Angeles 12, California, is the owner. The claim covers a vein of white limestone 10 feet wide which is reported to carry strontianite.

McAntire and Proctor marble deposit is 10 miles south of Baker and 4½ miles east of Soda. A. B. McAntire, 7721 South Main Street, Los Angeles and Elmo Proctor, Yermo, were listed as owners in 1943 (Tucker, W.B. 43, p. 524). The variegated marble forms a hill 400 feet above the desert level. The property is undeveloped.

Mill Creek Limestone Company's deposit comprising the NE¼ NW¼ and NE¼ NE¼ sec. 22; E½ SW¼, SE¼ and S½ of NE¼ sec. 15, T. 1 S., R. 1 E., S.B., is on the north side of Mill Creek, about 2 miles above Fallvale and about 23 miles east of Redlands; elevation is 6850 feet. Owner is Mill Creek Limestone Company, John D. Scouller, vice president, 6009 Santa Monica Boulevard, Los Angeles; the property is leased to Douglas Lime Products Company, L. C. Douglas, president, Wrightwood, California.

The crystalline limestone deposit some 60 to 70 feet thick, occurs between granitic walls. Strike is N. 50° E., dip 45° NW. The outcrop may be traced for a half a mile or more in an eastward direction some 350 feet above Mill Creek on an extremely precipitous slope. Mill Creek here follows the San Andreas fault, trending north of west. The limestone is somewhat finely crystalline, white in color and appears to be free from impurities, except for slight iron stain on fracture faces, at the surface.

The deposit has been developed by a quarry the face of which is approximately 150 feet long by 60 feet high. Material from quarry goes onto grizzly (8-inch opening); oversize goes to a small jaw crusher, thence to a wooden chute 3 feet wide by 2 feet high. This chute is approximately 400 feet long on about 50° inclination; it discharges into a 200-ton bin built of poles at the level of the creek. Mill Creek Limestone Company operated the property in 1942-43.

Equipment consisted of compressor, drills, and air tugger for raising supplies to the quarry level. About a quarter of a mile down the creek from the quarry there are three dwellings used for the camp.

The last 2 miles of road to this property was completely washed out and filled with boulders, and the ground was covered with 2 feet of snow at the time of visit in January 1947 by Reid J. Sampson.

Five miles up the Mill Creek road from Mentone and 12 miles from the deposit, a grinding plant to treat the limestone was erected, and sold to L. C. Douglas. This provides the following flow sheet: At the plant, trucks dump into hopper to 16- by 20-inch jaw crusher, belt-driven by 50 horsepower motor; crusher set at $2\frac{1}{2}$ inches, to 20-inch belt conveyor to double deck vibrating screen, 12 and 24 mesh; oversize to Williams hammer mill; minus 12- plus 24-mesh into bunkers, minus 24-mesh to elevator to two conical air separators, oversize to bunkers, undersize to another air separator, oversize sacked; undersize to another air separator; all connected to dust collector system; all machines motor driven; capacity 15 tons per hour. The plant was idle at time of visit.

Mojave marl deposit is about 2 miles north of west of Wild, a siding on the Atchison, Topeka and Santa Fe Railway midway between Victorville and Barstow.

About 1930 a plant was built containing a Williams mill, and bins and conveyors for storing marl and loading it on railroad cars. This was operated for 3 years and marl was shipped for use in the citrus groves. There has been no reported production since 1932. Mojave Marl Company, San Bernardino, carried on the work.

O'Connell limestone and dolomite deposit is covered by two 160-acre association placer claims in secs. 8 and 9, T. 14 N., R. 16 E., S.B., 3 miles southeast of Ivanpah station on Union Pacific Railroad. The owners are J. J. O'Connell and associates, 437 North Oakhurst Drive, Beverly Hills, California, or 240 Cherokee Building, Hollywood, California. The following information and analyses have been supplied by S. E. Chiapella.

The outcrop of limestone and dolomite rises abruptly from low undulating hills, has a width of about 300 feet and a length of about 1 mile. The elevation is 3000 feet. The deposit is well suited for working by open pits. A direct road from the deposit to the railroad would be slightly over 2 miles long. Sufficient water for domestic use and milling could be had from Slaughter House Springs, which are near the northeast corner of section 9. The electric line of The California-Nevada Power Company

is 5 miles distant. From 1927-29 the property was under option to Emerson Gee and associates. All stone produced was shipped to West Coast Kalsomine Company, Los Angeles.

The limestone is suitable for calcining in rotary kilns and for making whiting, foundry flux, chicken grits, and some types of glass. Chiapella quotes the following analyses:

	Percent
Limestone—	
$CaCO_3$	96.64
SiO_2	1.87
$MgCO_3$	0.47
Al_2O_3	1.08
Fe_2O_3	0.08
Dolomite—	
$MgCO_3$	42.57
$CaCO_3$	56.14
Al_2O_3 and Fe_2O_3	0.54
SiO_2	1.01
Ignition loss	46.64

Parker marl deposit consists of 8 claims, 7 miles east of Barstow (Tucker, W. B. 31, p. 386). There is no record of any activity at these claims.

Peterson limestone deposit contains 95 acres in sec. 12, T. 5 N., R. 1 W., S.B., 7 miles north of Lucerne Post Office and 23 miles east of Victorville on the Atchison, Topeka and Santa Fe Railway. The following is from a field report by W. B. Tucker: The owner, Carl Peterson, Lucerne Post Office, leased the deposit in 1944 to Marter Mining Company, R. L. Richter president and manager, 530 West Sixth Street, Los Angeles.

The claims were located in 1932 and have been prospected for scheelite and talc, as there is a granite intrusive and a belt of tactite 100 feet wide to the west of the limestone. The mountain containing the deposit rises 600 feet above the surrounding desert to 4000 feet elevation. The belt of limestone is from 300 to 600 feet thick and 4500 feet long, striking N. 30° W. and dipping 50° SW. It is cut by dikes of diorite. Work was started on the northwest slope early in 1944 and exposed a face of white crystalline limestone reported to carry 98.5 percent $CaCO_3$. The deposit has been worked by open cut. Equipment includes a 130-cubic-foot portable air compressor, jackhammers and a 5-ton truck.

The property has been a producer since early 1944. Limestone is hauled to Victorville for rail shipment to Los Angeles.

Richter dolomite deposit comprises two placer claims and two lode claims located on a low hill in north Lucerne Valley, in SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 15, T. 6 N., R. 1 W., 10 miles north of Lucerne Post Office and 30 miles northeast of Thorn Siding, on the Santa Fe Railroad; elevation 3300 feet; owner, Marter Mining Company, R. M. Richter, president and manager; Lawrence B. Martin, secretary, 530 West Sixth Street, Los Angeles.

The general strike of the dolomitic limestone beds is N. 20° W., dip 70° E. On the north slope of the hill the dolomite beds are cut by a granite intrusive dike, strike N. 50° E., dipping 45° NW. The

dolomitic beds are also cut by a network of stringers and veins of magnesite, ranging from 2 to 18 inches in width. One series of magnesite veins strikes east; the other series strikes north. Development consists of a number of open cuts and shallow shafts from 10 to 20 feet in depth. It is estimated the deposit contains 1,200,000 tons of commercial dolomite. The crystalline dolomite is white to brown in color, fine to medium grain. Two men were employed on development work in 1943.

Analysis of dolomite by Smith-Emery Company

	Percent
Silica (SiO_2)	0.46
Aluminum oxide (Al_2O_3)	1.05
Iron oxide (Fe_2O_3)	0.09
Calcium oxide (CaO)	34.64
Magnesium oxide (MgO)	23.97
Carbon dioxide (CO_2)	29.40
Moisture and combined water	9.97
Total	99.54

Riverside Portland Cement Company's Oro Grande quarry and plant were described in detail in several reports of this division, the latest being the one by Tucker and Sampson (43, pp. 524-525). This property, formerly operated by Golden State Portland Cement Company, was acquired June 1, 1923 by the present owners. It was idle from 1928-42, when it was reopened to produce clinker which was shipped to the company's Crestmore plant to make cement during the war. Limestone was quarried under contract from the deposit 2 miles east of the plant at the rate of 1000 to 1100 tons per day and delivered to the plant in 10-ton trucks. Nearly $400,000 was spent at that time to rehabilitate the cement plant, which was again closed after the war. The company has recently begun modernizing the plant by installing new kilns 350 by 10 feet, adding crushers and an air washer and putting in new mills for raw grinding as well as enlarging the finishing department. It is a dry-process plant formerly having a nominal capacity of 3000 barrels daily, which will be increased by the new work.

Silver Dome deposit is in sec. 9, T. 32 S., R. 42 E., M.D., 13 miles in an air-line northeast of Kramer, a station on The Atchison, Topeka and Santa Fe Railway near the Kern County line. A branch railroad, which formerly passed within 6 miles of the deposit on the west, has been removed. The 160 acres has been held for many years by Silver Dome Mining Company, address unknown.

The deposit is in a long, gently sloping hill, and has been estimated to contain several million tons of white crystalline high-calcium limestone. Only shallow cuts and short adits have been run for prospecting.

Silver Lake deposit is 3 miles west of Silver Lake, on 120 acres in secs. 18 and 19, T. 15 N., R. 8 E., S.B. The deposit is reported to be high-grade limestone without overburden.

Snowcap deposit is on 160 acres in sec. 30, T. 6 N., R. 13 E., S.B., on the southeast slope of the Bristol Mountains, 6 miles northeast of Amboy and about 1 mile from a paved highway.

The deposit is reported to be 700 feet thick by 1500 feet long and to be high-grade calcium carbonate, but no analysis is available. Garnet

occurs with the limestone, probably near a contact with an igneous rock which does not outcrop. The garnet zone is about 20 feet wide.

Robert Allison, Frank L. Furlow, 1755 Griffith Park Avenue, Los Angeles, and associates, have claimed the land for many years, but so far as known the limestone is undeveloped.

Snow White marble deposit is in the New York Mountains, 4 miles southwest of Barnwell. So far as known, it has not been developed.

Southwest Portland Cement Company's California plant is at Victorville. Limestone has been supplied from two large quarries, one of which is 6 miles northeast and the other, called Reserve quarry, 14 miles northeast of the plant. Late in 1946, they also purchased the Adelanto deposit on 320 acres of patented land in sec. 2, T. 6 N., R. 6 W., about 13 miles in an air-line northwest of Victorville. A railroad extends from the plant to the so-called main quarry 6 miles northeast, and an oiled road was built from this railroad 10½ miles to the Reserve quarry. Low-cost hauling of limestone over this road was developed, using units of a truck and trailer carrying 60 tons of stone at a trip in six separate-dump steel bodies which dump into railroad cars going to the plant.

For a description of the plant and quarry operations, see the report by Tucker and Sampson (43, pp. 525-528). The plant capacity is 7000 barrels a day.

Standard limestone deposit is 2 miles northeast of Ivanpah in sec. 20 (?) T. 15 N., R. 16 E., S.B., close to the line of the Union Pacific Railroad. As originally located, it contained six 160-acre placer claims held by Standard Lime Chemical Company. There is no record of any such company incorporated in California, and their address is unknown.

The deposit, at an elevation of 4000 feet, is white and gray crystalline limestone, but no analysis is available. It is undeveloped except for an old shaft 30 feet deep and old cuts along a former branch railroad.

Sugar Loaf Mountain dolomite deposit is on 60 acres on the north slope of Sugar Loaf Mountain, in sec. 17, T. 1 N., R. 2 E., S. B., at an elevation of 7000 feet. Albert Rose, Big Bear Lake Post Office, is the owner. The deposit is reported to be large. A partial analysis made by John Herman, Los Angeles, indicates 41.7 percent $MgCO_3$ and 53.6 percent $CaCO_3$ (Tucker, W. B. 43, p. 528).

Twin Buttes dolomite deposit, of 160 acres, is in the SW¼ sec. 9, T. 5 N., R. 15 E., S. B., 1½ miles southwest of Siam, a station on the Santa Fe Railroad; owner, Ira Judson Coe; under lease to C. I. Chubbuck, 5000 Worth Street, Los Angeles.

The deposit occurs as two dark-colored buttes rising from the plain on the northwest side of the Ship Mountains. They are composed entirely of dark-gray dolomite. The major axis of the larger butte is N. 40° E., paralleling the Ship Mountains. The dip of the dolomite is 25° SE and its length is 1500 feet; it has an average width of 700 feet, and a maximum height of 165 feet above the plain. The smaller butte lies 600 feet to the northeast, is 600 feet long and rises 125 feet above the plain. Estimated tonnage in the two buttes is 8,000,000.

Vaughan marble quarries (Tucker W. B. 43, p. 528) comprise two deposits of marble known as Lower Quarry Marble Tract and the Upper Quarry Marble Tract situated on the southwest slope of the Marble Mountains. The Lower Quarry Tract is in the NE$\frac{1}{4}$ sec. 11, T. 5 N., R. 14 E., and the SE$\frac{1}{4}$ sec. 2, T. 5 N., R. 14 E., S. B., and is 3$\frac{1}{2}$ miles southeast of Upper Quarry marble deposit and 2 miles north of Cadiz, a station on the Santa Fe Railroad; elevation 1500 feet. Upper Quarry Tract is situated on the west slope of Marble Mountains, in the NE$\frac{1}{4}$ sec. 28, NW$\frac{1}{4}$ sec. 27 and the SW$\frac{1}{4}$ sec. 22, all of sec. 26, T. 6 N., R. 14 E., S. B., 5 miles north of Cadiz; elevation is 1500 feet. Total holdings comprise 1440 acres, held by placer locations. Owner is Vaughan Marble Company, Arthur C. Vaughan, president, 437 South Hill Street, Los Angeles.

The Upper and Lower Quarry tracts are made up of sedimentary rocks of Cambrian age, consisting of quartzites, shales, and marbleized limestone. The beds strike N. 10° W., dip 35° E. Near the southern end of the Marble Mountains is a fault which strikes eastward; south of this fault the beds strike N. 70° W., dip 55° N. The beds of marble have an average thickness of 20 feet. On the Lower Quarry Tract, two quarries have been opened, from which blocks of marble weighing 15 to 20 tons were quarried. The marble is Calevanto, a highly colored, variegated marble. On the Upper Quarry Tract, the marble is fine grained and beds are 10 feet thick and of uniform quality. The marble beds occur at an elevation of 650 feet above the floor of the valley and extend to the top of Marble Mountain. The marble belt is about 2 miles in length by 1 mile in width.

Three quarries have been opened on the west slope of Marble Mountain and a small amount of marble extracted. The marble exposed in these quarries is black and gold and black and silver, overlain by a blue-black monumental marble reported to be equal to Perwick marble of Wales; also some Egyptian pebble marble has been exposed. From a report made by G. M. Butler of the Arizona School of Mines, the following analyses of marble and estimates were obtained:

Lower Quarry Tract—old quarry

	Percent
Calcium oxide (CaO)	48.15
Magnesium oxide (MgO)	2.48
Silica (SiO_2)	2.64
Iron (Fe_2O_3)	1.74
Aluminum (Al_2O_3)	1.66

Calcium carbonate 85.90 percent; magnesium carbonate 5.18 percent.

Butler estimated 2,000,000 cubic feet of commercial marble could be quarried.

Upper Quarry Tract

	Percent
Calcium oxide (CaO)	55.55
Magnesium oxide (MgO)	3.04
Silica (SiO_2)	1.98
Iron (Fe_2O_3)	0.77
Aluminum (Al_2O_3)	0.54

Computed calcium carbonate 90.18 percent; magnesium carbonate 6.35 percent.

It is estimated that there are 5,000,000 cubic feet of commercial marble available here.

These marble deposits were discovered and worked in 1937. Two thousand cubic feet of Calevanto marble was quarried from Lower Marble Tract. The property was acquired by Vaughan Marble Company in July 1939 and operated until October 1939; about 2000 cubic feet of marble was quarried. The blocks were sold to Musto Keenan Marble Company, Los Angeles, and California Marble Company, Los Angeles. The blocks of marble were sawed, polished and placed in the following buildings: Gardena Post Office; Oxnard Post Office; Mullen & Bluett Store, Pasadena; Financial Center Building, Los Angeles; United States Mint, San Francisco; Custom House, San Francisco.

The variety and quality of the marble that can be produced from these deposits, also the possibility that large blocks can be quarried, would indicate that in the post-war period there should be a large demand for the marble. The quarries are now idle.

Victorville Lime Rock Company., John S. Collbran, secretary, 5225 Wilshire Boulevard, Los Angeles, has leased from the Riverside Cement Company, 120 acres in the SW$\frac{1}{4}$ sec. 25, T. 6 N., R. 4 W., in addition to 570 acres which they own in sec. 36, T. 6 N., R. 4 W., approximately 5 miles northeast of Victorville.

The present quarry faces are in section 25, on the southwest slope of a ridge, the axis of which trends N. 20° - 30° W., which apparently is also the strike of the limestone, the dip being to the southwest. This ridge, approximately 3000 feet long, rising about 200 feet above the floor of the valley, is limestone, into which have been intruded numerous narrow diorite dikes. In some 1500 feet along the southwest slope six quarry faces have been opened. With one exception, these range from small open cuts to faces 50 feet high by 100 feet in length. The exceptional quarry consists of a cut about 30 feet wide driven 250 feet into the side hill, at the end of which the face is some 75 feet in diameter, with a maximum height of approximately 70 feet. Present work is in the northernmost quarry, the face of which is about 60 feet long by 20 feet high.

The material is loaded in 5-ton trucks by a $\frac{3}{8}$-cubic-yard Diesel shovel and hauled to the plant at Victorville. A LeRoi portable compressor supplies air for jackhammers drilling the face. Five men are employed at the quarry.

The plant flow-sheet consists of a 16- by 20-inch jaw crusher, elevator to bin to hammer mill, elevator to trommel with 20-, 16-, 4-mesh sections to vibrating screen 30 (?) mesh. Dust from the various machines is collected in a cyclone and sacked; other products go from four bins direct to railroad cars by shuttle conveyor. Products are used for glass, chicken feed, stucco, and lime. Capacity is about 50 tons in 14 hours.

Power is supplied by Southern Sierras Power Company. One man runs the plant.

The Furnace Limestone

This interesting formation was first described and named by Francis Edward Vaughan (22). His report covers the San Gorgonio quadrangle and a strip across the north end of San Jacinto quadrangle, and he mapped the areal geology from near Banning on the south to Lucerne Valley on the north, a length of 41 miles and a width of 29 miles. The

principal limestone areas mapped are in the high mountain region in T. 2 and 3 N., R. 1, 2 and 3 E., S. B., which ranges in elevation from 4500 to 8200 feet. The northern deposits of limestone, now being opened, are accessible by road from Thorne on the Santa Fe Railroad 4 miles south of Victorville, thence via Box S Ranch and Lucerne School to Monarch Flat, a distance of about 28 miles. The distance to railroad from the more southerly and higher deposits northeast of Big Bear Lake would be a few miles longer.

In his discussion of the limestone, Vaughan frequently alluded to areas of it, some of large size, which are sunken into the granite, and in many places altered to coarsely crystalline white marble. Granitic intrusions into the limestone are also frequently observed, with resulting contact minerals. Graphite, usually impure, was seen at one place in a stratum 1 to 4 feet thick. Between Crystal Peak and Marble Canyon he saw a limestone scarp 3000 feet high. South of Smarts Ranch (in sec. 3, T. 2 N., R. 2 E.) he found the distance across the strike of the limestone was 4700 feet. With the dip 60° SW., he calculated the thickness to be 4300 feet.

A. O. Woodford and T. A. Harriss (28) have described the Furnace limestone in a part of the area covered by Vaughan, but in greater detail. The following description and partial analyses are from their article. These notes refer especially to the limestone in the region of the Arlington Mining Corporation holdings, and the Dunton limestone deposit.

Approximate partial analyses, Furnace limestone, T. 3 N., R. 1 E., S. B., San Bernardino County (from Woodford and Harriss, 28)

Sample No.	1358B	1351D	1365B	1359A	1359C
$CaCO_3$	98.7	98.2	97.6	95.3	91.4
$MgCO_3$	1.0	1.3	0.8	1.9	1.3
$FeCO_3$					
Residue			0.4	2.2	6.8
	99.7	99.5	98.8	99.4	99.5

Sample No.	1360A	1358A	1367A	1363B
$CaCO_3$	89.4	68.7	60.5	55.7
$MgCO_3$	10.0	9.4	34.7	41.2
$FeCO_3$			0.9	0.6
Residue		21.8	4.7	1.4
	99.4	99.9	100.8	98.9

1358B—White sugary limestone, 500-600 feet SW. of NE. corner sec. 14, E. of Cushenberry Canyon.
1351D—Composite sample of white limestone along mountain front 1400-1500 feet west of mouth of Cushenberry Canyon.
1365B—Composite sample of white limestone along mountain front 100-300 feet NW. of ¼ sec. corner between secs. 8 and 17.
1359A—Dark gray limestone at ¼ sec. corner between secs. 13 and 14, E. of Cushenberry Canyon.
1359C—Composite sample, SW. wall of Cushenberry Canyon due W. of 1359A.
1360A—White limestone, about 800 feet SW. of center sec. 12, E. of Cushenberry Canyon.
1358A—Composite sample, east side of Monarch Flat, E. of Cushenberry Canyon. Varied materials including quartz vein.
1367A—Fine-grained white dolomite, SW. corner sec. 8, mountain front east of Furnace Canyon.
1363B—Gray dolomite from SW. corner sec. 16; analysis indicates 53 molecular per-cent $CaCO_3$.

"It is crystalline, the mineral individuals averaging about 1 mm. in diameter. Sometimes banding is pronounced, owing to variations in color or in grain (even up to 1 cm.) or both. The color bands are a few millimeters or centimeters wide and usually caused by vague changes in shade from light to dark gray. Some of the limestone is dazzlingly white, and much of the lower portion of the section, as here exposed, is stained red.

"Some parts of the limestone are composed of practically pure calcite; . . . sometimes dolomite grains are common and often tremolite is abundant as centimeter-long fibers or crystals radiating or variably oriented. A few beds are pure dolomite . . . there are also occasionally present chlorite, quartz, garnet, diopside, graphite, pyrite, wulfenite, galena, gold, etc. The banding is sometimes due to streaks of chlorite or other minerals. The red limestone is stained with hematite and limonite, which may be present in considerable percentage, often but not always accompanied by wulfenite in determinable amount and gold in commercial quantity. Rare limonite pseudomorphs after pyrite suggest the possibility that all the gold-bearing iron oxides have resulted from the decomposition of pyrite.

"Numerous poorly preserved fossils were found in a bed of fine-grained siliceous limestone at the top of the range scarp between the forks of Crystal Creek in the north central part of sec. 25, T. 3 N., R. 1 W. Dr. George H. Girty says '. . . the fauna is clearly Paleozoic and very probably Carboniferous . . . The only other possibility is Devonian and that may for the present be dismissed sans discussion. Both from what we have and what appears to be absent, I am inclined to believe that in the Carboniferous the geologic age is Mississippian rather than Pennsylvanian or Permian and that you have an horizon more or less equal to the Baird shale . . .'."

San Diego County

San Diego was the largest of the original 27 counties of the state. Major parts of San Bernardino and Inyo Counties were carved from it by the first state legislature in 1851. In 1889, Riverside County was formed from the northern half of the remainder, and in 1907 the area of the county was again reduced about 50 percent by the creation of Imperial County on the east. Many of the limestone deposits mentioned in old publications as being in San Diego County are therefore mentioned in Imperial and Riverside Counties in this report.

Although there are several limestone and marble deposits in the interior of the county, their development has been limited by the lack of rail transportation and the lack of any nearby market of importance except the city of San Diego, the rapid growth and importance of which have come only in recent years. Besides the railroad from the north which runs near the coast and has two short branches reaching only short distances inland, the San Diego & Eastern Railroad runs 22 miles northeast from San Diego to Lakeside, and the San Diego & Arizona Railroad serves a few townships in the extreme southeastern part of the county. The tentative boundaries of two state parks cover most of the eastern desert portion, or over 25 percent of the area of the county. Although only part of the land within these boundaries is actually under state control at present, the result is adverse to mining.

The Jurassic granitic rocks of the Peninsular Ranges outcrop over much of interior of the county and most of the limestone and marble deposits are roof pendants upon or partly invaded or enfolded by these intrusives. These limestones are probably Carboniferous. Marls near Lakeside and Otay are associated with the younger sediments.

The last recorded production of marble was in 1923; the last recorded production of lime was in 1925.

One of the earliest attempts to make Portland cement in California was started in 1889 on the Jamul Rancho 18 miles southeast of San Diego. It was a short-lived venture, due to cost of transportation.

Borrego Springs deposit is in secs. 2 and 3, T. 11 S., R. 7 E., S. B., 4½ miles from Borrego Springs. This is within the present boundaries of Borrego State Desert Park.

Blockman marble deposit is in sec. 2, T. 18 S., R. 8 E., S. B., in the southeast corner of the county 4½ miles east by good road from the San Diego & Arizona Railroad. It is a dark gray marble. There is no record of development.

Deer Park limestone deposit is 6 miles northeast of Descanso, in sec. 12, T. 15 S., R. 4 E., S. B. Many years ago white crystalline limestone was quarried from a lens 15 feet thick and burned in a kiln nearby for local use when gold mining was active on the adjacent Rancho Cuyama, now a state park.

Dos Cabezas limestone deposits are in secs. 22, 23, 26, and 27, T. 16 S., R. 8 E., S. B., about 1½ miles north of Dos Cabezas siding on the San Diego & Arizona Railroad.

Beds of white crystalline limestone varying in thickness from 20 to 100 feet (Tucker 25c, p. 370) are said to extend at intervals for a length of 1 mile with a strike of N. 30° W. and over a width of three-quarters of a mile. The limestone has been intruded by granitic rock and has some schist layers. It has been changed to marble of fine grain in some layers but the largest outcrop is a coarsely crystalline white limestone reported to carry 98 percent $CaCO_3$, and occurring on a hill 800 feet high. These deposits are idle and undeveloped, so far as known.

Elliott dolomite property comprises two 160-acre association placer claims in the S½ sec. 26 and adjacent parts of secs. 27, 34 and 35, T. 15 S., R. 8 E., S. B. The nearest loading station on San Diego & Arizona Railroad is 8 miles south. Mrs. Ellen Elliott Chilwell, Live Oak Springs via Pine Valley Post Office, California, Fred Elliott, Boulevard Post Office, California and others, are owners.

The deposit traverses a mountain 1500 feet high, a quarter of a mile wide and about a mile long, in the desert near the Imperial County line.

The following analysis was made by Smith Emery & Company, Los Angeles (No. 188685):

	Percent
Silica SiO_2	0.43
Iron oxide Fe_2O_3	0.10
Aluminum oxide Al_2O_3	0.25
Calcium oxide CaO	31.37
Magnesium oxide MgO	20.89
Carbon dioxide CO_2	46.70
Sulfuric anhydride SO_3	none
Phosphoric anhydride P_2O_5	trace
Acid insoluble matter	0.83
Purity as calcium-magnesium carbonate	98.8

Golden State marble deposits were located years ago by a company of this name in sec 21, T. 16 S., R. 8 E., S.B., within a mile of the line of the San Diego and Arizona Railroad. A bed of white marble outcrops 600 feet in length by 20 feet in width (Merrill 16a, p. 674) and a gray-blue bed has a width of 180 feet and length of 600 feet.

The company once had larger holdings of marble a few miles east in Imperial County, but never developed any of its deposits.

Heathman quarry, R. W. Heathman, owner, San Diego (in 1939), is in sec. 27, T. 16 S., R. 8 E., S.B., 1 mile north of Dos Cabezas siding. Thirty tons of white limestone was mined by open pit in 1939 from a deposit 10 feet wide.

Jamul Portland Cement Company was organized in San Diego County in 1889, to manufacture cement at a plant on Jamul Rancho, 18 miles east of San Diego (Irelan 90, p. 309). The erection of a plant was started in 1890 (Storms 93, p. 383) and it was finished in June 1891. It contained seven kilns and had a capacity of 150 barrels a day. The product was used for sidewalks in San Diego and according to Storms (93), it was also sold elsewhere in southern California. The project was evidently short-lived. It was said to cost more to haul the cement to San Diego than the cost of bringing English portland cement to California by water.

The following analysis of the "soft concretionary limestone" found on the property and used as raw material in making the cement is taken from Irelan (90), who does not mention what other ingredients were used.

	Percent
Silica	1.86
Alumina	1.10
Carbonate of lime	94.28
Carbonate of magnesia	1.19
Carbonates of alkalies	1.15

The composition of the cement was given as follows:

	Percent
Lime	65.2
Magnesia	1.20
Silica	24.00
Alumina	5.24
Iron peroxide	2.21
Alkalies	1.00
Sulphuric acid	0.20
Carbonic acid	1.00

Lakeside lime and marl deposit is on El Cajon Rancho, in the northeast corner of T. 15 S., R. 1 W., S.B., 3 miles north of Lakeside. The marl has a thickness of 2 to 4 feet, with a light overburden of soil. It has been used locally as soil corrective or fertilizer. According to a partial analysis quoted in past reports as having been made by the State Department of Agriculture, the $CaCO_3$ content of the product sold was 83.7 percent.

On Otay Mesa near Otay, a marl similar to that north of Lakeside was reported. Otaylite (montmorillonite) has been worked here extensively and possibly this was mistaken for limestone years ago.

Verruga marble quarries are in sec. 10, T. 11 S., R. 4 E., S.B. Eight patented claims were owned by John Johnson, Escondido, in 1939. The nearest railroad point is Lakeside, about 52 miles southwest. Road improvements in late years should permit hauling of marble at much less than the former cost, which was prohibitive when the quarries were last worked from 1921-23.

Two deposits of marble, 800 feet apart and separated by mica schist, occur in an area of metamorphic rocks near granite. The western deposit outcrops for about 1000 feet striking N. 20° W. and is about 100 feet wide. The eastern outcrop is reported to be 200 feet by 1000 feet. Two quarries were opened in the twenties on the western deposit and the marble was used in several buildings in San Diego. Some work was also done on the

eastern deposit. The marble is white, coarsely crystalline and of uniform texture and color. It is quite hard and can be quarried in large blocks.

San Luis Obispo County

This county is midway between Los Angeles and San Francisco and is traversed from north to south by a main state highway and the Southern Pacific Railroad. The population is small, and the local demand for lime in earlier days was supplied by a few small kilns, none active in the past 40 years. The only recorded production of limestone in the past 10 years has been from a large deposit on Lime Mountain in the northwestern part of the county. This has been used for beet-sugar refining.

The limestone seen in surface outcrops is generally buff, dust colored, or off white. That on the top of Lime Mountain shows abundant shell remains, passing downward into a dense, hard and compact, crystalline stone of medium crystal size, and fetid. Some shells found here indicated the Santa Margarita formation (upper Miocene age) as do specimens of *Ostrea titan* found in other beds nearer the coast. In the San Luis folio of the U.S. Geological Survey covering the southwestern part of the county, H. W. Fairbanks reported limestone derived from Foraminifera and attributed it to the Monterey (Miocene).

Dubost limestone deposit is on the Dubost Ranch in the NW$\frac{1}{4}$ sec. 30, T. 26 S., R. 10 E. and NE$\frac{1}{4}$ sec. 25, T. 26 S., R. 9 E., M.D. The property was assessed to Frank K. and Mary Dubost in 1946 and was being prospected by H. W. Gould & Company with a light diamond-drill outfit. It is about 19$\frac{1}{2}$ miles by road from Paso Robles.

The deposit extends for 3600 feet about N. 75° W. on this property, and for probably a quarter of a mile farther on adjacent land which slopes steeply toward Franklin Creek. From north to south it covers from 1200 to 1500 feet. The vertical range is 400 feet as measured by aneroid, the high ridge to the south rising 400 feet above the site of an old lime kiln where stone was quarried and burned on a small scale over 50 years ago. On the topographic map of the U. S. Geological Survey the summit of the ridge is shown to have an elevation of 1950 feet. The deposit is broken into terraces, dropping to the north, and indicating step faulting associated with two faults, one of which bounds the high ridge on the south and separates the Miocene limestone from the Jurassic rocks. The summit ridge, forming the highest terrace, shows the most extensive limestone outcrops. They are dust colored to white, somewhat siliceous, dense, hard, and of medium-crystalline texture. While it is undoubtedly of the same age as the Lime Mountain deposit, it shows much less fossil evidence and somewhat greater metamorphism, probably due to proximity to the faults. The second bench is 180 feet (aneroid) below the summit ridge, and is separated from it by a nearly vertical face, probably representing subsidence of this amount on the north side. The third or lowest bench, on which diamond drilling was going on at time of visit, is 100 feet vertically below the second. From there to the road level near the old kiln there is a gentler slope with an additional drop of 120 feet.

H. W. Gould & Company report that a total of 1742 feet of diamond drilling was done in 14 holes drilled in the lowest bench in 1946. They computed the average $CaCO_3$ content as 91.32 percent and the average SiO_2 content as 5.17 percent, including siliceous material deposited in the leached surface layer. They think a product carrying over 95 percent

$CaCO_3$ and a minimum of 2½ percent silica could be attained by proper screening. Only a few samples were analyzed for MgO, and these showed less than 0.25 percent. They estimate from preliminary examination that the deposit contains over 50,000,000 tons, of which only 1,000,000 to 2,000,000 tons has been tested by drilling and analysis.

The writer took a surface sample across a width of about half a mile along the summit of the ridge from east to west. This gave the following analyses as reported by Abbot A Hanks, Inc.

Insoluble	Fe & Al oxides	$CaCO_3$	$MgCO_3$
5.59%	0.60%	92.8%	0.81%

The deposit is favorably located for operation, with a good site for a plant. Water is reported to be available and late in 1946 electric power was only 1½ miles distant.

Lime Mountain Deposit (San Miguel Lime & Development Company). A total of 600 acres, comprising parts of secs. 9, 10, and 15, T. 26 S., R. 9 E., M.D., is assessed to Ed. W. Bolt. The limestone deposit forms the flattish top and upper slopes of Lime Mountain, elevation 2271 feet, in the west half of section 15. The limestone-covered area at the 2000-foot contour is about 90 acres. San Miguel, the rail shipping point, is 26 miles to the northeast. Of this, all but 2 miles is dirt road but with the steeper parts favoring loaded trucks.

Charles Taylor began development of the deposit about 1932 and the first reported sale of limestone was in 1933. From 1933-43 the property has been the sole limestone producer in the county. The stone has been found satisfactory for making lime in vertical kilns for use in refining beet sugar, and substantial sales have been made for that use, particularly at Salinas. Taylor transferred his interests about 1943 to the present holder, who made large shipments in 1945. Plans and surveys have been made for road changes and improvements, as well as for the possible building of a railroad spur to the deposit, and shipments were temporarily suspended in 1946, to await realization of some of these plans. Production was resumed in 1947. Drilling and examinations are reported to indicate 75,000,000 tons or more, but details were not available at the time of the author's visit in May 1946, when no one was on the property.

Several small quarries have been opened near the top of the mountain. The three smallest, which gave only limited backs, appear to have been idle recently. The later work was done from the south slope with the floor at 2130 feet elevation (aneroid). This had been opened for a distance of 325 feet east to west and for a maximum advance south to north, of 150 feet. The highest part of the face was 100 feet above the floor in May 1946, and the quarry floor was triangular in plan. In the total distance of 325 feet, there was a core of solid stone 175 feet thick, surrounded by broken and blocky rock which made considerable waste. The old northwest pit is about 165 by 225 feet with a maximum depth of 40 feet below the tip of the mountain. There is another old quarry at 1975 feet elevation (aneroid) just southwest of the main quarry. Much of the face of this old quarry is in loose slide rock.

The limestone is light buff to off white in color. On the surface near the summit, shells are common, including a large mussel classified as *Mytilus coalingensis* by G. Dallas Hanna of the California Academy of Sciences. This indicates the Santa Margarita formation of upper Miocene

age. The surface layer carrying loose shells is underlain by a few feet of distinctly fossiliferous limestone showing such shells, passing in depth to a tough and compact stone in which the crystals are of medium size, showing few broken shell remains, but giving the fetid ordor of stinkstein when hammered.

The following analyses of two samples were made by Abbot A. Hanks, Inc., June 1946. No 1 was taken across 175 feet in the new quarry at a depth of 100 feet. No 2 was from the old northwest quarry.

Analyses of limestone, Lime Mountain, San Luis Obispo County

	Insoluble Percent	Fe & Al oxides Percent	$CaCO_3$ Percent	$MgCO_3$ Percent
No. 1	3.19	0.50	95.15	1.06
No. 2	3.80	0.39	94.61	1.10

Although no one was available at the property to show property lines or advise depth to which limestone has been proved by drilling, the area of the outcrop, and the work already done in the quarries are sufficient to indicate a large deposit. The limestone outcrop is continuous for 2500 feet from east to west across the summit of the mountain, and about 1225 feet north to south, as measured by pacing. A deposit of these dimensions would contain about 25,520,000 tons per 100 feet in depth. The floor of the old quarry on the southwest side of the mountain is at 1975 feet elevation (aneroid) or nearly 300 feet below the summit. On the north side, the slope is covered by soil and brush and no limestone in place and little float was seen below 2050 feet elevation. A little below this, a small open cut is marked ''Test hole No. 2, Elevation 289 feet.'' This shows soil underlain by brown sandy shale. No outcrops of any rock except limestone were noted within the limestone-covered area described.

In the past, the limestone broken in the open quarries by bank blasting has been loaded on trucks by a Northwest shovel operated by a 4-cylinder gasoline engine and with a 1-cubic-yard bucket. It was hauled a few hundred feet to a rock breaker powered by a 4-cylinder Diesel engine. Crushed stone, 2 to 6 inches, was sent by a short belt conveyor to bins on the east slope for loading on trucks. An Ingersoll-Rand 250 portable compressor furnished air for drills.

The road from the new quarry level drops over 1300 feet in less than 5 miles.

Lopez Canyon group of three claims was located in 1924 close to the southeastern corner of sec. 36, T. 30 S., R. 13 E., M.D., where Fern Canyon enters Lopez Canyon from the west, about 7 miles due east of San Luis Obispo. The bottom of Lopez Canyan has an elevation of 1200 feet there, while the ridge on the west rises to elevations of 2300 to 2800 feet with no road within 4 miles in that direction. A road runs 15 miles from Arroyo Grande (on the railroad) to the claims.

The Monterey beds, of which the limestone here forms a part, lie in a deep syncline in this region according to H. W. Fairbanks (04), and the determination of actual thickness is also rendered difficult by brush. An apparent thickness of 100 feet or more is reported at the mouth of Fern Canyon, with dip of 45° SW.

No analysis of the limestone is available. A little of it was burned experimentally by the owners in a small kiln. So far as known there has been no recent activity.

Tassajara group of 3 claims is in secs. 21 and 28, T. 29 S., R. 12 E., M.D., on a deposit of coarse crystalline white limestone on the east slope of the Santa Lucia Mountains near the summit, at the head of Tassajara Creek. It is 3 miles from the highway and railroad.

Veins of limestone, the largest 12 to 14 feet wide, have been traced the length of two claims and some prospecting was done in open cuts over 20 years ago (Laizure, C. McK 25, p. 522). The claims were owned then by S. Aumaier, San Luis Obispo. The limestone occurs in the lower Cretaceous (Toro) shale.

The following analysis was by Smith Emery & Company (Laizure, C. McK, p. 522).

SiO_2	Al_2O_3	Fe_2O_3	Mn_3O_4	CaO	MgO	Loss on ignition
0.45%	0.19%	0.85%	0.80%	54.24%	0.42	43.40

The following limestone deposits have been noted in past reports, but no details have been given.

Almaden deposit is in SW¼ sec. 34, T. 26 S., R. 10 E., M.D., it is fossiliferous limestone, and occurs at an elevation of 1500 feet.

Lowe, Porter, et al. formerly had deposits in the northwest part of T. 32 S., R. 16 E., and eastern part of T. 32 S., R. 15 E., M.D., 15 to 18 miles east of Arroyo Grande. It is an extensive deposit of buff-colored limestone.

Morgan deposit is in sec. 36, T. 32 S., R. 14 E., M.D. Dark-gray outcrops 30 to 40 feet wide are reported at intervals in isolated patches for some distance along the tops of ridges. Some of this material was burned 50 years ago in a kiln on section 35 adjoining. It is about 9 miles by unimproved road from Berros on the railroad.

Newsom marl deposit is near Newsom Springs and 2½ miles east of Arroyo Grande. A bed of soft limestone 6 feet thick outcrops on a hillside. Some lime was burned 50 years ago or more.

Nipomo Deposit. Soft marly limestone reported near Nipomo was used long ago to make lime.

Oak Flat, west of Paso Robles, has been mentioned in old reports as the site of a lime kiln nearly 60 years ago. Some outcrops of light-buff limestone are to be seen, some of it being rather siliceous, but no old quarry site was found.

Santa Margarita deposit 2 to 3 miles north of San Luis Obispo, is reported to show a width of 20 feet of brown crystalline limestone over a length of a mile.

Shell deposits of good size occur near the Oceanic mine and on San Simeon Creek 4 or 5 miles inland.

San Mateo County

The geology of San Mateo County has been shown in the San Francisco and Santa Cruz folios of the U. S. Geological Survey. The areal geologic mapping of the first-named folio was done largely by students and instructors in geology in the state university, and for the Santa Cruz folio much work was carried on by similar groups from Leland Stanford

Junior University. As might be expected, the work was therefore done in adequate detail and under supervision of well-known geologists familiar with the areas.

The pre-Franciscan (Gabilan) limestone occurs as inclusions in the quartz diorite commonly called "Montara granite." Only one such occurrence has been mapped that is of possible commercial size. It is $1\frac{1}{4}$ miles west of Crystal Springs Reservoir on the west side of the Pilarcitos fault in W$\frac{1}{2}$ sec. 11, T. 5 S., R. 5 W., M.D.

The foraminiferal Franciscan (Calera) limestone outcrops in association with more or less chert, from the shoreline at Rockaway Beach in 2 narrow interrupted bands half a mile to 1 mile apart, which extend southeast for 11 miles on the east side of Pilarcitos fault. In this county the limestone has been utilized principally as crushed rock, and has been quarried over a long period of time at Rockaway Beach.

Some unusual occurrences of Eocene limestone are shown on the Santa Cruz folio at Langley Hill and Mindego Hill, 2 miles northeast and 3 miles southeast, respectively, from La Honda. They are described as clastic dikes, varying in width from less than 1 inch to over 30 feet, and up to 150 feet long, enclosed in tuff underlain by diabase.

By far the most important limestone deposits in the county are the Recent accumulations of oyster, clam, and mussel shells on the floor of south San Francisco Bay, between Millbrae and Alviso. These are being used in large quantities for making cement, and also for agricultural limestone.

Notes of limestone quarries being worked to supply crushed rock have been supplied through the courtesy of Henry H. Symons, Assistant Mining Engineer of the Division of Mines.

Pacific Portland Cement Company, 417 Montgomery Street, San Francisco, erected its Portland cement plant at Redwood City in 1924 and enlarged it in 1927. The plant has a capacity of 6000 barrels of cement a day, and uses the wet process. The company controls 30,000 acres on the floor of south San Francisco Bay on both sides of the channel from Millbrae to Alviso. The accumulation of Recent clam, oyster, and mussel shells found here represents a reserve of tens of millions of tons of good-grade limestone, and the other ingredients for cement are present in the sand and mud of the bay bottom. Suction dredges are used to lift shells and mud to barges alongside, which are then taken to the wharf at the plant where they are unloaded by overhead crane bucket.

Besides the principal use for making cement, the company also markets "Empire Brand Agricultural Lime" and limestone for other uses. The cement plant at Cement, Solano County, was closed some years ago and the limestone quarry operated so long near Cool, El Dorado County, has not been active since 1940, so that the company's present operations in limestone in California are centered at the Redwood City plant, with smaller-scale operation irregularly at the San Juan Bautista cement plant (formerly Old Mission Portland Cement Company), which has a capacity of 2500 barrels.

The following are analyses of the shell limestone made by C. A. Newhall. Analyses 1, 2, and 3 are of fresh, clean shells of clams, oysters, and mussels; 4, 5, and 6 are the average, high and low, of old shells, from 10 analyses:

	Percent SiO_2	Percent Al_2O_3	Percent Fe_2O_3	Percent $CaCO_3$	Percent $MgCO_3$
1	1.08	0.93	0.07	93.34	1.76
2	0.09	0.17	0.38	94.01	0.23
3	0.20	0.00	0.16	95.68	tr.
4	0.56	0.31	0.19	95.34	tr.
5	0.00	0.16	0.18	96.69	tr.
6	1.16	0.78	0.14	92.57	tr.

Partial analyses of the ''Empire Brand Agricultural Lime'' have been made by the State Department of Agriculture and showed the following contents of $CaCO_3$: 95.9, 95.7, 94.78, and 94.2 percent. About two-thirds of this material will pass 100-mesh and 93 percent will pass 40-mesh screen, according to an analysis made in 1943.

Rockaway Quarry, Incorporated, Post Office Box 108, Rockaway Beach, is the present operator of the property known for many years as Rockaway quarry. It adjoins the ocean about 10 miles south of the San Francisco County line and was a source of stone for contractors previous to 1919, when it was closed because of increased freight rates. This company began work in 1942 and has been an important producer of rock used for concrete aggregate and ballast, but so far as known has not sold the stone for its limestone content.

The deposit is of Franciscan (Jurassic?) limestone and chert, forming Calera Hill which rises 300 feet above sea-level. The chert occurs as lenses and nodules, and silica has also perhaps infiltrated the limestone. Acceptable limestone might be obtained by selective mining or by crushing and flotation, and apparently some lime was made here many years ago, as Eckel mentioned remains of some old kilns seen there.

The following analysis of the stone was made by Curtis & Tompkins, Ltd., 236 Front Street, San Francisco, in 1939:

	Percent
Insoluble matter (sand, silicates, etc.)	27.65
Soluble iron oxide and alumina	1.78
Calcium oxide (equivalent to $CaCO_3$=68.47 percent)	38.35
Magnesia (MgO)	0.34
Ignition loss	31.88
Water soluble alkalinity (as Na_2CO_3)	nil

Ken Royce Construction Equipment Company, 185 Bay Shore Boulevard, San Francisco, began work early in 1944 on a deposit of limestone on 190 acres of land in Rancho San Pedro (unsurveyed) just south of the town of Rockaway Beach and on the east side of the Ocean Shore highway.

The deposit is part of the Calera (Franciscan) limestone with which more or less chert is associated. It lies on a hill just south of Calera Valley, and was partly covered by soil when work started. The stone is hard, dense, and bluish gray. A quarry was opened and the limestone is being sold as crushed rock for concrete aggregate. The following analysis, reported as made by Abbot A. Hanks, Incorporated, July 10, 1945, has been supplied by the operator.

	Percent
SiO_2	5.1
Fe_2O_3	0.49
Al_2O_3	1.05
$CaCO_3$	91.7
$MgCO_3$	1.62
	99.96

W. O. Tyson, 345 Hilton Street, Redwood City, operates a quarry on the road from Belmont to Half Moon Bay, about 1 mile west of Skyline Boulevard, and just above Crystal Springs Lake.

The deposit is near a fault and this is probably the reason the limestone mass is found to be broken mostly to about 2-inch and finer sizes, with chert in blocks a foot or more thick.

A bulldozer is used to remove overburden and to push the rock into a glory hole. A tunnel below carries a belt conveyor, onto which rock is fed. The conveyor delivers to a grizzly through which 2-inch and finer rock drops into bunkers. Coarser pieces rejected by the grizzly are hand sorted, limestone going to a crusher and chert being thrown aside. Trucks load from the bunkers.

Vasquez quarry, 1½ miles southeast of Miramar, was operated for a short time about 1920, and the product was locally called limestone. The late C. A. Waring (Huguenin, E. 21, p. 179) made two analyses of this material which are reprinted here. The material is an arkose, consisting mostly of feldspar and calcite.

	Percent	*Percent*
SiO_2	45.78	45.63
Al_2O_3	11.98	12.14
Fe_2O_3	.50	.45
FeO	.10	.05
CaO	21.27	21.29
MgO	1.82	1.87
Na_2O	2.89	3.06
K_2O	1.49	1.35
H_2O	1.40	1.50
TiO_2	.25	.30
P_2O_5	.14	.13
CO_2	13.02	12.96
	100.64	100.73

Santa Barbara County

Previous to 1919, limestone for beet-sugar refining was quarried from a deposit on the north side of San Miguelito Canyon, 6 miles southwest of Lompoc. Recorded production from 1902-19 inclusive had a total value of $314,855 and included some lime produced in 1912-13. The deposit was worked out in 1919.

Although Miocene formations outcrop over large areas near the coast, limestone deposits have not been developed elsewhere in the region. A "compact, hard limestone containing much sand, tiny pebbles and broken shells" was reported in Irelan 88, p. 539, to occur between Las Cruces and Gaviota Pass. The same report mentions cherty limestone extending nearly to the seashore in the same locality, and a "white, compact magnesian limestone" occurring "in ledges about six feet in thickness" within 200 yards of the seashore and about 12 miles east of Gaviota. It is probably Miocene. Another similar deposit is mentioned by W. B. Tucker (25, p. 553) on Las Positas Rancho 3 miles west of Santa Barbara. None of these have been developed.

Lind deposit is 6 miles southwest of Lompoc on the south side of San Miguelito Canyon, opposite the deposit first mentioned above. It is reported to contain too much $MgCO_3$ to permit its use for beet-sugar refining, and has remained undeveloped.

Lomo Blanco Lithographic Stone Company has been mentioned in several of our past reports in connection with a deposit of fine-grained limestone which is found near the summit of the Santa Ynez Mountains. After being tested and examined more closely, it was found to contain veinlets of silica and calcite which were reported to render it of doubtful value for lithographic use. The deposit is more fully described below under *Sierra Blanca limestone.*

Near *Los Prietos* mercury mines, south of the serpentine in which the mines lie, there is a deposit of limestone. It is about 8 miles north of Santa Barbara and is undeveloped.

Sierra Blanca limestone is 14 miles east of north of Santa Barbara on and near Sierra Blanca Mountain, in the north part of T. 6 N., R. 26 W., S. B. The mountain is 4700 feet high and the region is rough and devoid of roads, the nearest being 8 miles distant.

According to Richard N. Nelson (25), the limestone is 200 feet thick in Indian Canyon (in section 6), gradually decreasing in thickness to the east and finally disappearing a little over a mile west of Mono Creek (section 11). It rests upon the Mono shale (Cretaceous or Eocene) and is overlain by Miocene.

Except for the upper 10 or 15 feet, Nelson describes it as ''a remarkably pure, massive, almost white organic limestone.'' Some of it is fine-grained and granular while elsewhere it shows outlines of small shells. In thin section, the most conspicuous forms were seen to be recrystallized Foraminifera of Eocene age.

The deposit has also been described by M. F. Keenan (32).

Santa Clara County

Considerable lime was burned in Santa Clara County in early days, and the operations have been fully described in the older reports of the State Mining Bureau. The county was among those earliest settled, and easily accessible from San Francisco. The production of lime in the county (not counting that used in the sugar industry) stopped in the early eighties but was resumed in 1908 on a small scale and continued until 1913. Since then, no production has been recorded. Limestone was marketed in small quantities, usually a few thousand tons annually, over a long period until 1940 when production jumped to 190,753 tons, increasing to 280,125 tons in 1941, but dropping to 45,274 tons in 1945. This includes shells as well as hard limestone.

The hard limestone deposits are in the Franciscan Calera formation (Jurassic?) which extends southeast along the west side of the county, and is bounded on the southwest by the San Andreas fault. Much of the eastern part of the county is also occupied by Franciscan rocks, but development of limestone has been in the western belt. When carefully sampled and mined selectively, a high-calcium limestone of good grade is obtainable from these deposits. However, the limestone is associated with narrow bands and larger masses of chert which render it undesirably siliceous when mined by methods usually required with such a low priced product. This difficulty was noted in 1889, in a discussion of the Guadalupe Lime Company (Irelan 90), where it was said

"One special feature of the lime has been noted and complained of by the parties using the same, that is, the quick setting of the lime when made up as

mortar. This is rather a property of cement than of lime, and indicates the presence of silicates in the lime. A close examination of the quarries reveals that the limestone is interstratified with narrow bands of chert often dark colored, and then easily separated by hand, but the limestone itself is often dark or the chert light in color, thus rendering the segregation of the chert well nigh impossible, and it thus finds its way into the kiln."

Eckel (29, p. 357) alluded to the condition as follows:

"The entire question of commercial utilization of these Franciscan limestones depends upon this matter of contained chert, not merely upon the amount of silica present in that form, but upon the way in which it is distributed in the limestone beds. For this reason, each individual tract upon which it is proposed to quarry the Calera limestone should require special study and prospecting; it is impossible to take for granted that the conditions found in one set of ouctrops will be the same (so far as working conditions are concerned) as those occurring a mile away. There are always beds of high-grade limestone in the Calera formation, but the question always is how much chert must be handled, to produce a ton of high-grade merchantable stone."

Since the above were written, flotation has solved the problem of beneficiating such limestones. It is now possible to raise the $CaCO_3$ content to 90 percent by this method, and the process can be used on very finely ground stone. Fluorescent (ultra-violet) light can also be used to make hand-sorting from belt conveyors more effective. The chert fluoresces with a different color than the pure limestone, permitting easy separation.

In December 1939, a portland cement plant began operation at Permanente near Los Altos, Santa Clara County. It is a wet-process plant utilizing the chert-bearing limestone of Black Mountain. Besides making cement, this company has also been producing limestone, especially for sugar refining.

Bay Shell Company, 503 Market Street, San Francisco, began operation about 1924 and has reported production every year since. They pump shells from the south arm of San Francisco Bay near Alviso. Shells are unloaded from barges by an overhead crane, dried in a rotary oil-fired kiln, screened, and crushed partly in a hammer mill and partly in rolls. Fine- and medium-sized products are sold for use in fertilizers and as chicken grits.

Beck Dredging Company, Capt. L. H. Beck, 305 Parrott Drive, San Mateo, has been producing shell lime since 1931. The plant is near Alviso, at the south end of San Francisco Bay. Limestone is sold for agricultural use, poultry grits, etc.

Bernal marl and limestone deposit is 3 miles by road southwest of Edenvale, a town on the railroad and highway 4 miles southeast of San Jose.

A hard bluish-gray limestone occurs over an area of 100 acres and is overlain by a soft marl, the thickness of marl being irregular. The deposit is on the east slope of the Santa Teresa Mountains and the total thickness of limestone is claimed to be 200 feet.

The marl has been worked at intervals since 1915, the last reported production having been in 1938, by California Lime Marl Fertilizer Company. It was sold for agricultural use. Thirty years ago several thousand tons of the hard limestone was used in beet-sugar refining. Work has recently been reported under way to reopen the deposit, by Los Gatos Construction Company, Los Gatos.

The following is an analysis of the marl supplied by the operator in 1919.

	Percent
Silica	2.50
Alumina	11.24
Iron oxide	2.90
Magnesia	1.55
Calcium carbonate	80.81

A partial analysis by the State Department of Agriculture in 1937 of the product then being marketed as "Bernal's Carbonate of Lime" showed 79.2 percent $CaCO_3$ equivalent.

Bond limestone deposit is on 80 acres in sec. 14, T. 7 S., R. 3 W., M. D., on the west side of Black Mountain 10 miles by road southwest of Los Altos. The following analysis quoted by Franke (30a, p. 9), should probably be considered as a picked sample in view of what is written elsewhere in this report about the Calera limestone.

	Percent
SiO_2	1.08
Fe_2O_3	0.64
CaO	54.99
$CaCO_3$	98.20
MgO	0.25
$MgCO_3$	0.52
Loss on ignition	43.14
SO_3	0.02

California Lime Marl Fertilizer Company, see Bernal.

Clark Ranch is 7 miles by road east of Madrone, a station on the Southern Pacific Railroad 18 miles southeast of San Jose. A deposit of "hydraulic limestone" on this land was noted by Watts (90a, p. 619), but so far as known has not been worked.

Douglas Ranch or Ellis limestone deposit is in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 27, T. 8 S., R. 1 W., 2$\frac{1}{2}$ miles by road from Los Gatos (Irelan 88, pp. 544-545). In 1886, 900 tons of this limestone was shipped to a sugar refinery at Alvarado and in 1889 and 1890 the quarries supplied the kiln of Los Gatos Lime Company, about 2 miles distant. The first quarry opened showed a width of 18 feet composed of "alternate layers of black bituminous limestone interstratified with dark-colored chert" but other openings exposed a thickness of over 100 feet. The stone is fine-grained with a flinty fracture and with bands and masses of chert, as is characteristic of the Calera limestone. The color ranges from white in narrow calcite veinlets, to black.

The only shipment of limestone from Los Gatos in recent years of which we have a record, was in 1938 by Basic-Limestone Products Company. Possibly it came from this deposit.

Lyndon deposit has been mentioned by Edwin C. Eckel (33) as containing both Calera limestone and later travertine. It is reported to be about 2 miles east of Lyndon, a railroad point south of Los Gatos.

W. B. Ortley Shell Company, Alviso, produced shells near Alviso from 1930-41. Shells were pumped from the bay by a rotary pump mounted on a barge and after drying for several days were put through a rotary kiln fired by natural gas. They were then elevated and run

through a rotary screen. Coarse shells were crushed in rolls in closed circuit with the screen. Crushed shells were sold for poultry food.

Santa Clara Holding Company's quarry is in secs. 17 and 18, T. 7 S., R. 2 W., M.D. This is in the locality where Permanente Cement Company is now operating. The land is on the east slope of Black Mountain and is 3 to 4 miles west of Simla, a railroad point. It may be called a type locality for the Calera (Franciscan) limestone. When freed from chert and shale it made good lime for beet-sugar refining and was so used for many years by El Dorado Sugar Company and Alameda Sugar Company. Several small quarries were worked but the property had been idle many years up to 1934, when the company shipped some limestone from Simla.

The above refers to the shallower aspects of the limestone, and fuller details are given under Permanente.

San Jose Cement Company (which lapsed as a corporation as of March 4, 1936), was mentioned by Franke (30a) as owner of a deposit of limestone on 331 acres of land in secs. 4 and 5, T. 9 S., R. 1 E., and sec. 32, T. 8 S., R. 1 E., M.D.

This land is about 4 miles west of New Almaden and southeast of the Guadalupe mine, a region where quicksilver was mined first in 1824. The only recorded limestone production in the vicinity was in early days by Guadalupe Lime Company, who operated quarries and kilns on the south side of Capitancillos Creek $2\frac{1}{2}$ miles from Guadalupe.

Permanente Cement Company (Black Mountain Limestone Deposits). The summit of Black Mountain, 2787 feet high, is near the southwest corner of sec. 13, T. 7 S., R. 3 W., about 15 miles due west of San Jose. It is the most prominent natural feature of the area of Franciscan rocks which extends southwest along the west side of the county, with a width here of $3\frac{3}{4}$ miles. Limestone deposits have been mentioned on the long eastward slope, on the west side and on the southwest flank. The production has been entirely from the more accessible eastern side in secs. 17 and 18, T. 7 S., R. 2 W., about 5 miles west of Monta Vista, where stone was quarried on a small scale to make lime for sugar refining. No detailed information was published up to the time the Permanente Cement Company began work in 1939 and the few analyses available were evidently of selected or sorted rock. It was known, however, that the limestone was generally more or less siliceous and for that reason no effort had been made to use it for cement.

The great mass of the mountain lies between the San Andreas fault and a branch fault called the Black Mountain fault which starts in Portola Valley several miles northwest and crosses the Page Mill road on the north side of the mountain, east of the main fault. This area between the faults was badly shattered by the 1906 earthquake (Lawson 08, vol. 1, pt. 1, p. 107) although it is not clear whether the abundant cracks found over the surface are to be attributed to the boldness of the topography or to the crushing of the wedge-shaped end of the fault block. According to the above report, "several days after the earthquake 345 cracks, large and small, were counted along the county road (Page Mill road) in a distance of less than 3 miles between these faults."

The interest in the Permanente plant was so great from the start that numerous technical articles on all phases of its operation have been

published. A list of these articles is given in the *Engineering Index*. For the purposes of this report, which is intended to give information primarily on the limestone resources of the state, the best of these articles is probably that by A. M. Kivari, entitled *Milling at the Permanente Cement Plant,* published first as Technical Publication 1359, American Institute of Mining and Metallurgical Engineers (1941) and later in Volume 148, Transactions, American Institute of Mining and Metallurgical Engineers (1942). A few details are given below from this article to fill out the meager information hitherto available about the Calera (Franciscan) limestone and the results of applying to its benefication the art of modern hydrometallurgy.

The limestone quarry is 45 miles south of San Francisco and 12 miles west of San Jose, at an elevation of 1850 feet. The overburden is only a few feet thick, and is easily removed. As the limestone is well fractured it is seldom necessary to use explosives. The quarry has been worked in benches by a 5-cubic-yard electric shovel which furnishes limestone to the conveying system at the rate of 5600 tons a day. The cement plant capacity of 12,000 barrels in early 1941 required about 3130 tons of limestone, 620 tons of "clay" (sandstone and andesite) and 100 tons of gypsum per 24 hours. The plant capacity was increased to 16,000 barrels late in 1941; capacity was increased again in 1943 and the plant became the world's largest. Further expansion is indicated in the accompanying information furnished by Permanente Cement Company. A stockpile of 550,000 tons is maintained for the cement plant and in the autumn, when the beet-sugar refineries demand large tonnages of limestone, another stockpile of 100,000 tons is made.

In a geologic report on the property, the late Professor C. F. Tolman and J. V. Neuman Jr., of Stanford University, estimated about 30,000,000 tons of proven and 18,000,000 tons of possible limestone. They distinguished two main types of limestone. The first is platy, dark blue gray, colored by hydrocarbon residue and usually finely crystalline with occasional coarsely crystalline layers or spots. The second type is white to gray, dense, and usually has a conchoidal fracture. It contains chert bands that lower the average $CaCO_3$ content to between 50 and 75 percent. They mapped the following beds:

1. Light, cherty and dark limestone, portions running 80 to 95 percent $CaCO_3$ and other parts 60 to 75 percent.
2. Sandstone and andesite.
3. Lower cherty white limestone requiring benefication.
4. Sandstone and andesite.
5. Dark limestone averaging 86 percent $CaCO_3$, about 200 feet thick.
6. Upper cherty light limestone.
7. Andesite.
8. White cherty limestone, varying in thickness from 10 to 160 feet, requiring benefication.
9. Sandstone, tuffs, and andesite.
10. Dark cherty limestone, 75 to 100 feet thick, requiring benefication.
11. Fine-grained andesite.
12. Complex folded and sheared limestone, sandstone and andesite, requiring benefication.
13. Undifferentiated Franciscan sandstone, shale and andesite.

The average chemical composition of numerous samples from four limestone beds was quoted by Kivari as follows, raw basis:

Average analyses, Permanente limestone

	1	2	3	4
SiO_2	29.23	12.86	7.24	4.18
CaO	38.04	47.48	50.96	52.74
Fe_2O_3	0.54	0.54	0.42	0.32
Al_2O_3	1.26	1.12	0.60	0.66
MgO	0.24	0.27	0.04	0.05
Ignition loss	30.66	37.70	40.48	41.90
Total	99.97	99.97	99.74	99.85
$CaCO_3$	68.4	85.12	91.39	94.67

The plant and methods used to beneficiate limestone for cement making in 1941 were described in detail by Kivari. This included the use of the Breerwood flotation process in which the only reagent used was talloel. It was saponified to the desired degree at the plant with caustic soda and diluted with water. About 0.8 of a pound of reagent was used per ton of dry solids. This process is no longer used.

*Current Developments, Permanente Cement Company.** In line with the current industrial growth of the West Coast, Permanente Cement Company is nearing completion of an expansion program which will boost its plant's annual production by some 500,000 barrels, or two million sacks of cement.

Officials of the Henry J. Kaiser-sponsored plant, located 10 miles west of San Jose, California, pointed out that the plant is already the world's largest cement mill and that the new facilities and changes effected will push its annual productive capacity to a peak of 5,500,000 barrels—10 percent more than its present rated capacity.

The availability of high-quality raw materials, limestone and clay, is partially responsible for Permanente's new production goal. Located immediately above the mill on plant property, Permanente operates a quarry from which it takes 6,000 tons of limestone in an 8-hour shift. Over a period of 1 year, a quarry force of 19 men move approximately 1,500,000 tons of limestone downhill to the processing plant.

Novel in operation of the quarry is the 48-inch conveyor belt by which rock moves to the mile-distant plant at the rate of 1,000 tons an hour. The plant throughout uses more than 4 miles of conveyor belting. After induction motors start the conveyors, generators driven by gravity flow supply enough electricity to operate a five-yard shovel in the quarry.

Limestone not suitable for manufacturing cement, is used to produce high-quality commercial rock for concrete aggregates, railroad ballast, highway paving material and other similar products.

Starting with changes in the raw grinding department, new facilities include four Fuller coolers for Permanente's kilns, an additional kiln feed slurry tank, new clinker conveying and crushing facilities, additional cement pumping equipment under the storage silos, and enlargement of the packhouse.

The California cement plant is not only the world's largest; it also employs revolutionary production methods made possible by varied equipment of special design.

A unique closed-circuit method of raw grinding in the mill building assures accurate control of fineness. This raw-grinding circuit produces slurry of which 95 percent will pass through a 200-mesh sieve that has

* Supplied by Permanente Cement Company, Kaiser Building, 1924 Broadway, Oakland 12, California.

40,000 openings per square inch. New improvements in methods generally used in closed-circuit raw grinding have already been put into practice, the result being an increased productive capacity of 10 percent.

To take care of this additional raw slurry another kiln feed slurry tank of 13,500-barrel capacity is being installed. During kiln-down time the slurry tank, Permanente's third, will be used for storage, enabling raw grinding to continue.

Fuller coolers are being installed—two are already in operation—on Permanente's four mammoth rotary kilns which are 12 feet in diameter by 463 feet long. In the kilns calcining takes place under temperatures of 2700° F. Following the calcining process, resulting clinker will be cooled much more efficiently by the new Fuller coolers, thus enabling increased kiln capacity.

Clinker is then reduced to finished cement in primary and secondary grinding mills in closed circuit with air separators. Because of increased kiln production it was necessary to install a new clinker conveying and crushing system. This is composed of two gyratory crushers both of which are closed-circuited with vibrating screens. Here the clinker will be reduced to minus three-eighths inch.

An additional 6-inch Fuller-Kenyon pump is being installed under the 500,000-barrel cement storage silos. This fifth pump will greatly facilitate pumping cement to the packhouse.

The packhouse addition consists of a four-compartment, 5,000-barrel packer bin which can be used either for bulk loading or feeding a Bates C-113, four-spout packer. This addition was installed so that Permanente can competently handle sacking of the 17 types of cement now being produced.

Construction of Shasta Dam provided the occasion for the birth of Permanente Cement Company. As a result of competitive bidding Kaiser and his associates were awarded the cement contract for this greatest of overflow dams, even before they had a plant constructed to manufacture the required cement.

In June 1939, ground was broken in the western foothills of Santa Clara Valley, near San Jose, California; on Christmas Day, or less than seven months later, the first barrel of cement was produced.

Permanente furnished the entire 6,800,000 barrels of cement used for Shasta Dam and, by the end of World War II, had filled major government contracts totaling $25,000,000. A notable example of one war job consisted of supplying all the bulk cement for military fortifications in the Pacific area up to July 1945.

This latter contract was made possible due to the fact that Permanente Steamship Company had acquired two ships and were making plans to refit them for bulk use when Pacific hostilities broke out. These vessels, the S.S. Permanente and S.S. Philippa, went into action in May 1942, giving the United States a total of four bulk cement carriers with an average capacity of 40,000 barrels each. One-way passage required about 10 days.

Today, Permanente produces 17 different kinds of cement, including Standard Portland, Modified Portland, Hi-Early Strength, Low-Heat, Sulphate Resisting, Plastic, Concrete Pipe Cement, three types of oil well cement, Plastite, and Brick Mix. High Magnesia Building Lime, as produced by The Permanente Metals Corporation at Natividad, is also marketed by the Permanente Cement Company.

Since the war a booming construction business has required all the cement Permanente can produce, and the Kaiser organization is now serving the great northwest and the Hawaiian Islands, as well as its home northern California market.

At Seattle, Washington, and Honolulu, T. H., receiving, storage, and packing equipment have been installed. Located at Merced, California, similar facilities serve eastern and central California. Bulk loading and shipping facilities are situated at Port of Redwood City, on San Francisco Bay, for shipments to Seattle and Honolulu.

Winship deposit is in the SW¼ sec. 13, T. 7 S., R. 3 W., on the southwest side of Black Mountain. It is about 8 miles by road from a point on the railroad just south of Los Altos. So far as known, it is undeveloped. The following is an analysis by Sidney A. Tibbetts of Berkeley, of a sample taken by Walter W. Bradley, but it is not known how much of this grade of limestone is available (Franke 30a).

	Percent
SiO_2	1.56
Al_2O_3	0.47
Fe_2O_3	0.22
Mn_3O_4	0.05
P_2O_5	0.06
$CaCO_3$	97.20
$MgCO_3$	0.43

Wright's Ranch marble deposit, 5 miles southeast of New Almaden mine was described by Crawford (94, p. 394). It is reported to show an outcrop from 60 feet to over 100 feet wide and over 3000 feet long. It is described as mostly light gray, curiously mottled by light blotches and streaks in a darker crystalline groundmass. Samples took a high polish. Although believed to be a promising deposit, it has not been commercially developed. It is near Llagas Creek, some 9 or 10 miles by road from Madrone, a station on the Southern Pacific Railroad.

Santa Cruz County

The important deposits of Gavilan (pre-Franciscan) limestone in Santa Cruz County are within 8 miles northwest of the city of Santa Cruz, and for years production has come partly from within the city limits. The limestone is associated with a micaceous schist of similar age and is considerably folded, crushed and generally altered to a fine-grained gray-mottled marble or coarsely crystalline blue to white calcite marble with minor amounts of impurities. These deposits have made the county one of the more important producers of limestone for cement, lime, and miscellaneous uses. There are about 14 deposits, of which 8 or 9 are large enough to be important, in two areas of a few square miles each on the south slope of Ben Lomond Mountain between San Vicente Creek and San Lorenzo River. The limestone and associated larger areas of schist lie on the quartz diorite (Montara granite) of the mountain, or are partly embedded in it. The areal geology has been mapped by Branner, Newsom, and Arnold (09). Edwin C. Eckel (33) estimated the total exposures of Gavilan limestone here as between 600 and 700 acres, and he regarded the present separate deposits as parts of what were formerly larger beds that were intruded by the quartz diorite. The accompanying schist has evidently protected the limestone from intense contact metamorphism except in a few places.

In recent years (since 1927) five lime or limestone producers operated in the district. Only three of these have been steady producers. The production of lime in Santa Cruz County was started by I. E. Davis and A. P. Jordan in 1851. In 1867, it was said that 100,000 barrels of lime was used annually in San Francisco, three quarters of which was "obtained from the vicinity of Santa Cruz on the ranch of the Cañada del Rincon" (Browne, J. R. 68). There has therefore been a large production from the county for which the Division of Mines has no complete record, as the systematic collection of such statistics by the State Mining Bureau did not begin until 1894 for Santa Cruz County. From 1894 to 1929 the total lime output was 6,113,983 barrels, valued at $6,606,998. Since then, with only one or two producers, figures for output have not been published in detail in order to not reveal details of private business. However, over a long period of years it is safe to say that the county produced from a quarter to a third of all lime made in California. For 10 years past there has been only one lime producer in the county. Most of the limestone quarried for other purposes has been used by one portland cement plant with a capacity of 10,000 barrels a day. Several companies have participated in limestone production for miscellaneous uses.

The following analyses of Santa Cruz County Gavilan limestone were quoted from Eckel (33). Samples 1 to 5 inclusive were taken by Eckel and analyzed by H. R. Brandenberg (Cowell Portland Cement Company). Sample 6 was taken and analyzed by C. A. Newhall.

Analyses of Gavilan (Paleozoic?) limestone, Santa Cruz County

No.	Silica (SiO_2)	Alumina (Al_2O_3)	Iron oxide (Fe_2O_3)	Lime carbonate ($CaCO_3$)
1	0.52	0.28	0.22	95.87
2	1.28	0.31	0.31	94.95
3	0.50	0.21	0.19	95.54
4	0.22	0.22	0.22	97.09
5	0.54	0.22	0.26	97.61
6	1.28	0.04	0.54	94.00

No.	Lime (CaO)	Magnesium carbonate ($MgCO_3$)	Magnesia (MgO)	Carbon dioxide (CO_2)
1	54.06	2.81	1.34	43.66
2	53.38	2.90	1.38	48.30
3	54.09	2.77	1.32	43.46
4	55.00	1.68	0.80	43.60
5	54.90	1.13	0.54	43.54
6	n. d.	2.93	n. d.	n. d.

(Analyses 1 and 6 from Bonnie Doon quarry; 2 to 5, Cowell quarries, near Felton).

The reserves of limestone in this region are quite large, and are capable of supplying limestone at recent rates of production for a long time in the future.

Henry Cowell Lime & Cement Company is now the only lime producer in the county. The main office is at 2 Market Street, San Francisco. Henry Cowell, founder of the company, and well known as owner and operator of limestone deposits and lime kilns in other parts of the state, operated in Santa Cruz County as a member of the firm of Davis

& Cowell in the eighties, at the pioneer lime plant which had been established in 1851 by I. E. Davis and A. P. Jordan, about a mile northwest of Santa Cruz. He later formed the company bearing his name and extended his limestone holdings northward. The largest deposit of limestone known in the district, according to Eckel (33), is located near the Cowell Home Ranch and contains 200 acres. Other smaller deposits are near it.

The quarry worked in late years is 2 miles northwest of Santa Cruz and 1.9 miles by road from Rincon, a railroad station where the lime plant now used is situated. However, over the long period of operation, a number of quarries have been opened from 1 mile to 3½ miles from Santa Cruz, and the I.X.L. quarries 2½ miles west of Felton were also operated but have been idle since 1919. At the latter place, the limestone occurs on a point at the junction of two canyons, and dips nearly vertically. Backs of about 400 feet were available and one quarry face was 200 feet high and 300 feet wide. The stone is coarsely crystalline and considerably shattered.

In recent quarrying (2 miles northwest of Santa Cruz), jackhammers with detachable bits have been used for drilling and black powder and dynamite for blasting. Limestone is trucked to the kilns at Rincon. The limestone usually has an overburden of a few feet of clay. The size of quarries varies, the larger having a face over 100 feet high and an area of several acres.

Pot kilns were used at both the upper and lower quarries, and at the I.X.L. quarry. Wood was used for fuel, and 4½ to 5 days were required to burn a charge. Three such kilns at the I.X.L. works produced 1600 to 1700 barrels of lime a week. The combined capacity of six kilns at the quarries 1 and 2 miles northwest of Santa Cruz was 2500 to 3000 barrels of lime a week, during the dry season. Later four Standard 34-foot continuous kilns were built at Rincon on the railroad. These were satisfactory for burning dense fine-grained limestone, but not for the coarsely crystalline stone. They required sorting of rock for character and size of feed, adding to expense. They fell into disuse and three pot kilns were built at Rincon to handle all the limestone. Each kiln has a capacity of 1600 barrels. Fuel oil with steam atomization is used for firing, with four burners and four draw doors on each kiln. From 4 to 4½ days is required for burning, 36 to 48 hours for cooling and 2 to 3 days for drawing the lime, the last depending on the number of men available. During the war, with labor scarce and expensive, the crew of men was greatly reduced, and only 15 men were employed at the quarry and lime plant. Lime barrels are made at the plant.

Holmes Lime Company began lime burning in this county in the early eighties near Felton, and continued work there until 1936. Since then title to the property passed to Santa Cruz County Title Company, Santa Cruz.

The limestone quarries were on a steep hill rising 1000 feet about 2 miles west-northwest of Felton. Several quarry faces, the highest near the summit, were operated. The limestone occurs interbedded with mica schist. It was white, varied from finely to coarsely crystalline and was considerably shattered. The layers of limestone were said to be 50 or 60 feet thick.

The company was an important lime producer, reporting, for example, an output of 220,000 barrels of lime for the two years ended September 1, 1890, and 70,000 barrels in 1893. Most of the lime was burned in pot kilns near Felton, and in later years a hydrate plant of 25 tons daily capacity was also operated. Continuous kilns were tried here also, but evidently did not prove satisfactory for the shattered, coarsely crystalline limestone.

Pacific Limestone Products Company was organized in 1922 and has been in operation since as a producer of limestone for a variety of uses. The main office, quarry, and plant are at the end of Spring Street, Santa Cruz. The property and operations have been described by Laizure (26) and Hubbard (43a) in such detail that little could be added.

When the company was organized it took over the Caplatzi quarry which had been supplying limestone for fertilizer, poultry food, flux, etc. Later the Miller, or Thurber quarry, which had been producing limestone for macadam and concrete work, was absorbed. The raw limestone is marketed under the trade name ''Kalkar'' for use in stucco dash, poultry grit, cattle and poultry feeds, fertilizer, fillers, terrazo, roofing grit, mortar sand and macadam, and part of the waste from removing overburden is sold for fill material.

The deposit shows more contact metamorphism than noted in most deposits of the region. A. A. Fitch (31) listed numerous contact-metamorphic minerals, including diopside, forsterite, and others characteristic of contact zones altered by granitic intrusives. The crystals of the altered limestone are of all sizes from very fine to 4 inches on a side. Irregular vertical fissures are filled with broken limestone cemented by fine-grained calcite and black opaline silica occasionally carrying pyrite and arsenopyrite. The limestone is bluish white and considerably shattered. It has an overburden of 2 to 8 feet of soil and red clay. The average height of face has been about 80 feet. Because of the mineral impurities, the material is hand sorted and hand loaded.

The crushing units include a 14- by 42-inch primary jaw crusher, 10- by 36-inch secondary jaw crusher, and a hammer mill. Three units of four-deck Rotex screens separate finely ground rock and five sizes of granular products. A set of 12- by 16-inch rolls and a ring-roll Sturtevant mill handle screen tailing and scalpings and a further separation is made in a 6-foot Sturtevant centrifugal air separator. A crew of 20 to 25 men is employed throughout the year.

Santa Cruz Portland Cement Company's plant at Davenport and the quarry on San Vicente Creek 3 miles north of the plant in sec. 15, T. 10 S., R. 3 W., M.D., have been illustrated and described by Hubbard (43), Laizure (26), and Young (25). Robert A. Kinzie Sr., consulting engineer, and Robert A. Kinzie Jr., plant superintendent have described phases of the operations in publications of the American Institute of Mining and Metallurgical Engineers.

The cement plant has been in operation since 1907. It has a capacity of 10,000 barrels daily and makes portland and high-silica cements. The land holdings are about 1100 acres.

The limestone deposit is stripped under contract and is quarried by a combination of glory hole, transfer raises, bulldozing chambers, chute-loading and adit transportation. The deposit has the appearance of a roof pendant but does not show evidence of contact metamorphism

near the surface; the effects are those of regional dynamic metamorphism, where the limestone has been recrystallized as a coarsely crystalline semi-marble. There was reported to be 500 feet of backs above the haulage tunnels. The width of deposit is 1000 to 1200 feet and the length is reported to be from 2800 feet to three quarters of a mile. The quarry-run material is said to have from 85 to 92 percent $CaCO_3$, the balance being mostly "clay."

An analysis made in 1911 agrees closely with others previously quoted for the district.

	Percent
$CaCO_3$	95.97
$MgCO_3$	1.34
Fe_2O_3	0.60
Al_2O_3	0.73
SiO_2	1.42

The manufacture of 10,000 barrels of cement a day requires mining about 2,000 tons of limestone. The company was the first to make use on this coast of bulk loading of a specially designed ocean-going steamer for transporting cement, in conjunction with cement silos and packing plants which were built at Portland, Oakland, Stockton, and Long Beach. A special pier 2327 feet long extending to deep water at Davenport, and carrying the pipes for loading the cement on the steamer, was required. The steamer has a cargo capacity of 422,712 cubic feet.

Shasta County

High-calcium limestone probably occurs in greater abundance in Shasta County than in any similar area in California, and much of it is easily accessible from present roads. The limestone extracted from the deposits has been limited to that needed for local uses, because of the distance from large consuming centers. If really cheap electric power is made available from Shasta Dam there should be a good possibility of developing industries in the county that can utilize at least part of the immense beds of high-calcium limestone. The presence of large deposits of lignite or sub-bituminous coal is also a factor worth considering, as it offers a cheap local fuel.

It will be seen by reference to the section on uses of limestone that a great variety of products could be made in the county which have sales values sufficiently high to take care of freight rates to markets. Whether or not the local advantages of cheap power and fuel would be sufficient to neutralize the cost of the longer haul, would depend on the type of product.

The McCloud limestone appears to be of great prospective interest because of nearness to the railroad and the size of the bodies near the site of the old U. S. Fish Hatchery at Baird, although the creation of Shasta Dam has resulted in flooding the approaches to the lower levels of some of the deposits. These limestone bodies cover part of section 12, nearly all of section 13 and parts of secs. 14, 23, 24, and 26, T. 34 N., R. 4 W., parts of secs. 6, 7 and 18, T. 34 N., R. 3 W., and outcrop farther north at frequent intervals for miles into the mountains northeast of Castella. The Gray Rocks deposit in sec. 3, T. 33 N., R. 4 W., from half a mile to $1\frac{1}{2}$ miles south of Pit River, is now within 1 mile of the relocated Southern Pacific main line, which here is 3 miles east of the old line. The deposit rises to an elevation of over 2400 feet, more

than 1300 feet above the dam level. The Moxley deposit, covering most of sec. 13, T. 34 N., R. 4 W., is all above the dam, rising from 1500 feet to over 3100 feet elevation. Very large deposits of this limestone extend north across the west sides of T. 35 and 36 N., R. 3 W., but are at present in a region lacking roads, and rather mountainous.

Geology

In 1855, John B. Trask, first State Geologist, gathered fossils from the McCloud limestone near Bass' Ranch (Gray Rocks deposit), and these were classified as Carboniferous (Pennsylvanian). This classification was confirmed by the second (Whitney) survey in the sixties.

This limestone was later studied by J. W. Beede and Hedwig T. Kniker (24); Harry E. Wheeler (36); and Norman E. A. Hinds (33). Beede and Kniker considered the relation of the Permian and Pennsylvanian section (in California) still uncertain because of the meagerness of the data available due to physical conditions of the deposits, but concluded that the "balance of evidence seems to be that the beds are referable to the base of the Permian in the sense in which American basal Permian beds are treated in this paper." The work of Wheeler added 14 species from the lower and middle McCloud limestone to the 12 listed in 1864 by Meek. Wheeler concluded that

"Nearly the entire fauna bears closer affinities with Eurasian species than with those of the other Anthracolithic faunal provinces of North America.

"*Schwagerina robusta* (Meek), *Pseudofusulina gracilis* (Meek) and *Omphalotrochus whitneyi* (Meek) indicate an Uralian age for the lower part of the formation.

"The stage of evolution of the fusulines of the middle McCloud, together with certain molluscan criteria, suggests that these strata should be assigned to the Artinskian (lowermost European Permian) stage. The relatively unfossiliferous strata of the upper part of the McCloud have not been correlated."

Hinds mapped the McCloud limestone as Permian. His description of the formation is the best the author has seen, and is quoted in full.

"The McCloud limestone, conformably overlying the Baird formation and in turn overlain by the Nosoni beds along the west side of the McCloud canyon, can be traced more or less continuously from the northern border of the Redding quadrangle for about 25 miles to the south where it disappears near the settlement of Lilienthal. At its southern extremity, the limestone appears as lenses, but a short distance to the north it gradually thickens, becomes continuous, and, north of the Gray Rocks, is a prominent member of the stratigraphic column. The limestone is exceedingly resistant to erosion and forms bold, rugged ridges or mountains wherever it is exposed; along the eastern side of the McCloud River, great, jagged limestone peaks are the most conspicuous feature of the landscape. The McCloud, through most of its thickness, is composed of pale gray to dark gray fine-textured marble; practically none of the original limestone remains. Most of the rock is massive, but finer-stratified zones also are present. Locally, and especially along igneous contacts, the recrystallization has been much coarser and generally the gray color has been bleached out leaving a very pale gray or white rock. Chert layers, lenses, and nodules have been developed apparently as a result of metamorphism by solutions associated with igneous intrusions; these siliceous zones are more resistant to weathering than the limestone and consequently they stand out rather conspicuously from the limestone surfaces. They are also pale brownish or buff in color and contrast with the normal gray of the limestone. At the southernmost exposures near Lilienthal, the McCloud is about 200 feet thick while along the east side of the McCloud Canyon it reaches a maximum of 2000 feet on Horse and Town mountains. The McCloud limestone is so highly fossiliferous that most weathering surfaces show some representation of the fauna. Beds composed of cup corals, protozoa, and crinoid stems are common. Internal structures have been commonly destroyed by recrystallization. The fauna consists chiefly of corals and protozoa (Fusulina); brachiopods and gastropods are fairly abundant. Crinoid stems in great profusion are present but complete individuals are rare. According to Diller [06] the age of the McCloud

is Pennsylvanian, but recent work by H. A. Wheeler [private communication] of Stanford University has shown that the fauna is of Lower Permian age and that the Pennsylvanian is not represented in this region.

"While the McCloud was laid down on the Baird strata, it is at present separated from the Baird throughout much of its extent by an enormous dike-like body of quartz-augite diorite which apparently came up along the contact of the two formations. The Baird and McCloud are in contact north of Hirz Mountain for about four miles and also south of Gray Rocks for about four miles. As a result of the intrusion of the diorite, the limestone was very greatly shattered and many huge blocks or xenoliths were engulfed in the dike-rock. These show up as isolated masses completely surrounded by the augite diorite along the whole length of the dike. Many of these xenoliths show more intensive recrystallization than the average of the formation. Along the contacts of the igneous body and the limestone, a considerable suite of metamorphic minerals have been developed of which hedenbergite, magnetite, and garnet are the most conspicuous. Small bodies of magnetite or magnetite rock containing various proportions of other minerals, principally garnet, are found along the contact within the limestone or within the igneous rock. Some magnetite was mined from these bodies on the west side of the McCloud canyon near the post office of Baird about one and one-half miles north of the junction of the Pit and McCloud rivers. The limestone has been used for flux at mines of the Bully Hill district farther to the east."

The Hosselkus (Triassic) limestone occurs in large deposits in T. 34 and 35 N., R. 2 W., north of Pit River, and along the highway for several miles east of Furnaceville in T. 33 and 34 N., R. 1 and 2 W. There are several smaller bodies, among which those surrounding Bear Mountain are nearest the railroad; other occurrences are in secs. 9, 16, and 31, T. 36 N., R. 2 W., and in sec. 1, T. 36 N., R. 3 W.; but these are too remote to be of present interest to possible users.

Limestone has been used from Brock Mountain deposit (old quarry in N½ sec. 8, T. 34 N., R. 2 W.,) and from the deposit east of Furnaceville (old quarry in sec. 1, T. 33 N., R. 2 W.) for smelting iron and copper ores, but all of these smelters were dismantled long ago. The writer has been fortunate in obtaining a number of analyses of the Hosselkus limestone from a company that examined and sampled the deposits in 1945, and these are quoted under the description of the Asher, Bear Mountain, and Brock Mountain deposits. These indicate a high-calcium stone with moderate amounts of silica, and little iron, aluminum, and magnesium. It is dark bluish-gray with numerous fossils, of which ammonites are commonest. If the analyses available are truly representative, it is more siliceous than the McCloud limestone, but the magnesium, iron, and aluminum content is lower. The total thickness of beds ranges from 50 to 200 feet.

The Kennett limestone (Devonian) has been used more than either the McCloud or Hosselkus stone, as the principal deposits of it were close to the railroad and to the copper smelters. The outcrops are small and scattered in comparison with those of the other two. The deposits occur principally west of Sacramento River, and those that have been developed are within a few miles of the railroad, in secs. 19, 22, 27, 28, 32, 33, and 34, T. 34 N., R. 5 W. Farther north, on the east side of the river, a long outcrop of Devonian rocks, extending 10 miles or more from Hazel Creek northeast to the county line contains limestone, so far not worked. There are also small deposits of the Kennett limestone in sec. 16, T. 34 N., R. 4 W., in sec. 6. T. 32 N., R. 4 W., and in sec. 31, T. 31 N., R. 5 W.

12—74191

Years ago, Holt and Gregg operated two limestone quarries, the first in section 34, and a later one farther west in the same section, in T. 34 N., R. 5 W. They had two kiln sites, one in Backbone Creek $1\frac{1}{2}$ miles north of Kennett and the other at Kennett. Alta Lime and Brick Company worked deposits in section 22 and had a kiln in sec. 24, T. 34 N., R. 5 W. Mountain Copper Company procured lime from a deposit in sec. 32, T. 34 N., R. 5 W. for use at their Keswick smelter. A small kiln was operated on the Briggsville deposit in sec. 31, T. 31 N., R. 5 W. No production has been reported from the county for nearly 20 years.

The Kennett limestone varies from light gray in the upper section to a dark bluish gray. It contains abundant fossils, mostly corals, and has been changed in large part to marble. In places it carries considerable chert. The few analyses available show 95 to 97 percent calcium carbonate, 1 to 4.4 percent silica, from $\frac{1}{2}$ to $2\frac{1}{4}$ percent magnesium carbonate, and very little iron oxide and alumina. However, it must have been on the average of good quality as lime made from it was used over a large part of northern California, the old kiln at Briggsville having supplied lime to many pioneer towns of early mining days, and the deposits near Kennett having been in operation from at least 1884 until 1925. Statistics beginning with 1896, credit the county with an output of 244,778 barrels of lime and 711,064 tons of limestone. The larger part of both came from the Kennett limestone deposits tributary to Kennett, although quarries in the Hosselkus limestone were operated near Furnaceville and on the west side of Brock Mountain.

Description of the Deposits

Alta Lime and Brick Company began work in 1904 on a deposit of Devonian limestone in sec. 22, T. 34 N., R. 5 W., 4 miles north of Kennett, and started a lime kiln in section 24. There is no further record of activity, although the largest area of Devonian limestone in the vicinity of Kennett is in section 22. The north half and southwest quarter of this section are now shown to be owned by the United States, and the southeast quarter is shown to be owned by E. J. Gorman, on the County Assessor's records.

Asher limestone deposit is owned by James Asher et al. This is part of the Hosselkus (Triassic) limestone 25 to 30 miles northeast of Redding on and near the highway leading to Alturas. The Asher land from which samples were taken for the analyses shown below, is in N$\frac{1}{2}$ lots 3 and 4, sec. 1, and NE$\frac{1}{4}$ lot 1, sec. 2, T. 33 N., R. 2 W., M.D., 1 to $1\frac{1}{2}$ miles northeast of Furnaceville; but the deposit is partly in each of 4 townships near their common corner. The highway runs on or alongside the deposit for several miles.

The Hosselkus limestone has been studied and described by several eminent geologists, including J. P. Smith and J. S. Diller, and the latter states that in this vicinity, "on the spur southwest of the mouth of Cedar Creek, two limestones occur, one 60 feet and the other approximately 100 feet thick, separated by 150 feet of dark shales. The whole set of beds dips to the southwest and is evidently overturned". It is rather hard, somewhat siliceous, dark colored, and shows numerous fossils, with corals abundant in the upper part.

It has been sampled recently because of its suitability for burning in vertical kilns. The following analyses are of "spot" samples taken

in 1945 by an engineer for a company using a large amount of limestone, and were analyzed in the company laboratory. The have asked that their name be withheld.

Analyses of Hosselkus (Triassic) limestone, Asher land, Shasta County

Sample No.	Percent SiO_2	Percent R_2O_3	Percent $CaCO_3$	Percent $MgCO_3$
1	2.21	.38	97.04	.42
2	4.05	.62	94.89	.59
3	.85	.45	98.55	.42
4	4.55	1.81	92.99	.21
5	.59	.32	98.81	.52
6	2.10	.20	97.29	.66
7	.95	.24	97.54	.52
8	.59	.20	99.56	.35
9	4.40	.44	94.51	.62
10	2.98	.55	95.65	.66
11	3.51	.53	95.01	.21
13	2.79	.47	95.65	.24
Average, omitting No. 8	2.63	.54	96.17	.46

Bayha Land Company, see Gray Rocks deposit.

Bear Mountain occupies most of the S½ sec. 12, T. 33 N., R. 4 W. and W½ sec. 7, T. 33 N., R. 3 W., about 12 miles in an airline north-northeast of Redding. A bed of Hosselkus limestone, 50 feet thick in places, forms an irregular ring around most of the mountain at an elevation of about 2000 feet. It is covered by Jurassic beds. A Forest Service road gives access to the limestone in section 7. No work has been done on the deposit, so far as known. A sample taken near the road was analyzed by a company interested in new sources of supply, and they have kindly made the analysis available, as follows:

	Percent
SiO_2	0.96
R_2O_3 (Fe_2O_3 and Al_2O_3)	0.58
$CaCO_3$	97.18
$MgCO_3$	0.69

Bibbens limestone deposit is owned by the Bibbens heirs. This is part of the large deposit described under Asher. This land is in SE¼SE¼SE¼ sec. 35, T. 34 N., R. 2 W.

Following is an analysis of the limestone:

Percent SiO_2	Percent R_2O_3 (Fe, Al oxides)	Percent $CaCO_3$	Percent $MgCO_3$
1.87	0.26	97.29	0.24

Brock Mountain Deposit. This is the largest outcrop of the Hosselkus (Triassic) limestone, covering half or more of secs. 4, 5, 8, and 9, T. 34 N., R. 2 W., north of Pit River. J. P. Smith (94, p. 606) published the results of his studies of this limestone in 1894. It is reported to have a total thickness of 200 feet and covers the sides and top of the mountain through a vertical range of over 1000 feet to well over 2500 feet elevation.

Smelters at Bully Hill and Afterthought mines used this limestone for flux. It was quarried in section 8 and J. S. Diller (06) quotes the average partial analysis as showing 51 percent CaO, 1.5 percent Fe_2O_3 and Al_2O_3, and 4 percent insoluble, equivalent to less than 93 percent

$CaCO_3$. This is considerably lower than the average of analyses given in this report for the Hosselkus limestone. It is hard, rather siliceous and bluish gray. Bones of large reptiles are reported to occur in it, as well as numerous other fossils.

No work has been done on this deposit since smelting was stopped. An old road formerly connected the quarry with Winthrop and Bully Hill, 5 and 6 miles distant, respectively. The following is a recent analysis of a "spot" sample from the old quarry face:

	Percent
SiO_2	1.64
R_2O_3 (Fe_2O_3 and Al_2O_3)	0.29
$CaCO_3$	96.68
$MgCO_3$	0.56

Sec. 5, T. 34 N., R. 2 W., is assessed to Southern Pacific Land Company. Sections 4 and 8 are unpatented and section 9 belongs to the United States.

Briggsville (Mooretown) limestone is on Clear Creek, in sec. 31, T. 31 N., R. 5 W., 6 miles by road from Girvan on the railroad. In the early gold-mining days Briggsville was an important camp, and the limestone from the deposit there was burned in a stone kiln and supplied an extensive area. No production is known to have been made since 1925 when J. H. Hill marketed a few hundred tons of slaked lime for agricultural use. Where seen by the writer, near the bank of Clear Creek in the north half of section 31, a lens of limestone nearly 100 feet thick outcrops on the slope near the roadside. The exact size could not be judged because it dips into the hill and is covered by black shale. It strikes northwest in a lens of Kennett (Devonian) formation which is about a mile long, with limestone exposed in separate outcrops for about half a mile.

Analysis of Briggsville limestone (Devonian)

Percent SiO_2	Percent R_2O_3	Percent $CaCO_3$	Percent $MgCO_3$
3.67	0.24	95.14	0.56

Doak deposit is now owned by the United States. It is in SE$\frac{1}{4}$ sec. 23, T. 34 N., R. 4 W. This is part of the McCloud limestone, between 1000 and 1600 feet in elevation, a quarter to half a mile southeast of the site of the old Baird Fishery, and east of McCloud River. It has not been developed, but another part of the deposit nearby in section 26 was worked over a long period of time and was found to be a high-calcium limestone. It is probable that analyses quoted for the latter under Shasta Iron Company would be very close to the figures obtainable for the Doak portion of deposit. The lower part of this deposit up to 1065 feet elevation will be flooded when water is high in Shasta Dam.

Emerald Glen Ranch, A. J. Woolsey trustee, et al. The deposit is 2 miles northeast of Ingot, near where the highway passes the corner common to T. 33 and 34 N., R. 1 and 2 W., on a deposit of the Hosselkus limestone. The limestone here is in two bodies, one 60 feet thick and the other 100 feet thick, the two being separated by 150 feet of dark shales. Spot samples were taken and analyzed in 1945 from the north part of sec. 6, T. 33 N., R. 1 W., and nearby in sec. 36, T. 34 N., R. 2 W., by a

company using much limestone; they have kindly made the following analyses available:

Analyses of Hosselkus limestone, 2 miles northeast of Ingot (Emerald Glen Ranch)

Percent SiO_2	Percent R_2O_3	Percent $CaCO_3$	Percent $MgCO_3$
3.39	0.44	95.52	0.21
2.75	0.40	95.90	0.45
0.63	0.50	98.30	0.31
2.21	0.28	96.91	0.35
1.89	0.29	96.91	0.45
1.08	0.32	97.79	0.52

This limestone would probably have many uses, including the making of lump lime. The distance from railroad, about 25 miles, is perhaps the chief factor in considering it. It lies at an elevation of 1200 to 1300 feet and grades favor traffic to the railroad at Redding.

Gray Rocks deposit of McCloud (Permian) limestone was known to the earlier geologists as *Bass' Ranch* deposit and has been described in some early Division of Mines reports under *Bayha Land Company.* It lies mostly in the E½ sec. 3, T. 33 N., R. 4 W., but part of the Lime Mountain Consolidated claim is in section 2. These lands are assessed to Theodore Barnes et al. On the north the limestone extends into secs. 34 and 35, T. 34 N., R. 4 W.

The deposit rises to an elevation of 2400 feet, or over 1300 feet above the level of Shasta Dam. Like most of this limestone, the deposit rests on a large intrusive dike of quartz-augite diorite which invaded the contact between it and the underlying Baird formation. This has shattered the limestone and the seams between the blocks have been filled by the intrusive, the result being a rather steep ridge covered by rough masses of limestone trending north. Due to the action of the intrusive, much of the limestone has been changed to gray fine-grained marble, with contact minerals and siliceous zones nearest the intrusive. It varies in thickness from a capping to a maximum of 800 feet on the north, according to H. W. Fairbanks (93).

The relocated main line of the Southern Pacific Railroad now passes 1 mile west of the summit of Gray Rocks, and the state highway crosses the western part of section 3.

There is no record of any production from this deposit.

Holt and Gregg deposit is owned by U. S. Smelting, Refining, & Mining Exploration Company, 921 Newhouse Building, Salt Lake City, and is located in W½ sec. 34, T. 34 N., R. 5 W. This quarry, and another worked before it, which is farther east in the same section, supplied lime for general use in the region, and also supplied large tonnages of limestone for copper-smelter flux to smelters at Kennett and Keswick. Practically no production has been made for 20 years.

It is Devonian limestone and was reported in 1896 to carry 97 percent calcium carbonate ($CaCO_3$), 2 percent magnesium carbonate and 1 percent silica. (Crawford, J. J. 96, p. 632). Another reported analysis, published in 1888 (Irelan, W. Jr. 88, p. 572), probably represented the stone from the first Holt and Gregg quarry, east of the later one. It was as follows:

	Percent
Carbonate of lime	95.2
Silica	4.4
Magnesia (carbonate?)	0.5
Carbon (organic)	Trace
Total	100.1

This deposit is now almost 6 miles from the railroad and separated from it by the water behind Shasta Dam.

Moxley deposit is in fractional sec. 13, T. 34 N., R. 4 W., most of which, except for half of the southeast quarter, is covered by the McCloud (Permian) limestone. The southwest quarter of the southwest quarter belongs to the state. All the balance is assessed to Thomas R. Woods. It forms the conspicuous mountain rising to an elevation of 3114 feet about 1½ miles northeast of Baird Fishery. In this region the limestone shows its greatest apparent thickness. The contact of the underlying quartz-augite diorite with limestone on the west is at an elevation of about 1500 feet. Of course the contour of the top of the intrusive is probably irregular, so that in the absence of careful examination and drilling or other prospecting, no very close estimates of tonnage can be made. However, an area of 267 acres (which is about half the area mapped as limestone in this section on the Redding folio of U. S. Geological Survey) would cover nearly 100,000,000 tons of limestone for each 100 feet in depth. In the Redding folio Diller (06) states it has a thickness here of "approximately 2000 feet." J. D. Whitney stated it was 1000 feet thick and H. W. Fairbanks believed it to be much greater, "probably twice that amount."

The description of McCloud limestone by Norman E. A. Hinds (33) previously quoted applies to this deposit and need not be repeated. The chemical character is indicated by analyses shown below.

For many years, this land and adjoining claims on the lower slopes of the mountain in sections 14 and 23 were held as a source of supply of limestone for a proposed portland cement plant by Shasta Cement Materials Association. The rise of the water behind Shasta Dam to a maximum level of 1065 feet elevation has changed conditions. The main line of the Southern Pacific Railroad is now only 2 miles southwest of the west line of section 13, and satisfactory arrangements could probably be made to deliver limestone to the west shore of the lake by barges, within a short distance of a spur track, or to a plant. The lake is about 4500 feet wide at the old fish-hatchery site.

The following are analyses of limestone samples taken by E. W. D. Johnson and the late M. E. Dittmar from the deposits. Dittmar was the moving spirit in Shasta Cement Materials Association, and supplied the analyses.

Analyses of McCloud limestone, secs. 13, 14, 23, T. 34 N., R. 4 W.

Sample No.	1	2	3	4	5
SiO_2	1.10	0.41	1.02	0.60	0.60
Iron oxide	0.20	0.49	0.20	0.30	0.30
Alumina	0.24	0.64	0.61	0.50	0.40
Magnesia	2.38	0.36	1.12		
$MgCO_3$				0.81	1.98
CaO	52.16				
$CaCO_3$		97.57	96.07	98.09	95.33
Loss on ignition	43.96				

1. By Smith Emery & Co., San Francisco. 2, 3, 4, 5. By Montana Assay Office, Portland, Ore. Samples reported to have been slightly weathered.

Mountain Copper Company. During the operation of the copper smelter at Keswick over 40 years ago, this company obtained limestone for smelter flux from a deposit of Devonian age principally in SE¼ sec. 32, T. 34 N., R. 5 W. So far as known, no work has been done there in recent years. The quarry is 7 miles from the present railroad and separated from it by Shasta Dam.

Shasta Cement Materials Association, c/o D. V. Saeltzer, Redding, has for 20 years or more held 320 acres of patented land containing shale in sec. 16, two 160-acre unpatented claims on limestone in secs. 14 and 23, and an option on the Moxley limestone deposit covering sec. 13, all in T. 34 N., R. 4 W. The limestone claims are the lower, western part of the immense deposit of McCloud limestone in sec. 13, and would be the logical place to begin quarrying. So far only assessment work has been done.

Before the erection of Shasta Dam the association had plans for building a cement plant on the low land between the limestone and McCloud River. The raising of water to a maximum of 1065 feet elevation behind the dam would prevent this now. However, the main-line railroad has been moved to within 2 miles of the deposit, and cheap barge transportation could no doubt be arranged across the lake with a landing in sec. 22 or 27 within a short distance of the railroad. The lake here is about 4500 feet wide at high level.

This property is said to have been considered for a plant to make cement for the dam, but no one supplied the necessary capital. With cheap electric power from the dam, and with an abundant supply of lignite or subbituminous coal only 16 miles distant, some plan should ultimately be worked out for the utilization of these deposits. It is not known whether or not the option on the Moxley land is still in effect.

For analyses of the limestone that would be developed by this project, see under *Moxley deposit.*

The shale deposit in sec. 16 is claimed to contain about 200,000,000 tons. Gypsum, also required in cement, occurs in the Bully Hill mine underground workings, but nothing is known of its quality or the practicability of mining it for such use from a depth of several hundred feet.

Shasta Iron Company deposit in N½ sec. 26, T. 34 N., R. 4 W., has been the only body of McCloud (Permian) limestone developed commercially. A quarry face 200 feet long by 100 feet high was opened and the stone was delivered to railroad cars at Heroult over a gravity tram 1600 feet long, for shipment to Bully Hill smelter. It was also used by Noble Electric Steel Company during their electric smelting operations at Heroult, where they smelted iron ore which occurs nearby in section 26 along the contact of the limestone and quartz-augite diorite. They leased the Shasta Iron Company lands and produced pig iron from 1907-14. During World War I they produced ferro-manganese and ferro-silicon. Then until 1925, considerable iron ore was mined and shipped to Pacific Coast furnaces. Although the former approach by rail has been flooded by the water behind Shasta Dam, the deposits are above the high-water level and the water would permit cheap transport by barges to points on the west shore near the railroad.

Analyses 1 and 2 below were furnished by Noble Electric Steel Company to the U. S. Geological Survey and published in *Mineral Resources of the United States* (Burchard, E. F. 12, p. 661). No. 3 was first quoted by Tucker (22, p. 733).

Analyses of McCloud (Permian) limestone, Shasta Iron Company quarry

Sample No.	Percent $CaCO_3$	Percent $MgCO_3$	Percent CaO	Percent MgO
1	97.57	0.76	----	----
2	97.65	0.72	----	----
3	----	----	53.80	1.12

Sample No.	Percent CO_2	Percent Fe_2O_3	Percent Al_2O_3	Percent SiO_2
1	----	0.52	0.64	0.41 (a)
2	----	0.45	0.41	0.40 (a)
3	43.25	FeO 0.20	0.61	1.02

(a) Insoluble in acid.

Sierra County

Numerous deposits of limestone have been noted in the Carboniferous rocks extending northwest across Sierra County. Most of them are along the eastern side of the metasediments from Loganville, a little west of Sierra City, to Eureka Peak in Plumas County. In this region the limestone is magnesian, of light or dirty gray color, and differs from the high-calcium limestone farther southwest, in color, composition, and probably in age, though the latter is not known to have been definitely determined. No fossil evidence has been found in these magnesian limestones. A chemical analysis by the U. S. Geological Survey of a sample from a limestone deposit north of Loganville showed the following:

	Percent
SiO_2	4.9
Iron oxide	0.36
Lime	31.33
Magnesia	19.61

Some of this magnesian limestone is associated with the iron (magnetite) deposits in the high mountains near the Plumas County line.

None of the deposits in Sierra County are near enough to a railroad to have commercial value at present. The largest and most accessible lens is about 5 miles east of Downieville, on the state highway.

Siskiyou County

The Oregon line of the Southern Pacific Railroad in Siskiyou County runs close to the eastern boundary of the older crystalline rocks, which to the east of the railroad are buried under younger barren volcanics. The limestone deposits of possible commercial value at present are those within reasonable trucking distance from west of the railroad. They are in Paleozoic formations. The development in past years has been limited to the production of limestone and a little lime for local use, and the shipment of small lots of lime from Gazelle in 1929-30, after which no production was reported until 1945. In that year, considerable limestone was shipped for use in beet-sugar refining.

The largest area of Paleozoic rocks in which the numerous deposits are found extends for a distance of 30 miles from Callahan on the south to Yreka on the north, and for 12 to 15 miles west of the railroad. Any deposit within this area would be within what is now considered trucking distance to the railroad. In many cases roads would have to

be built for a few miles to connect with one of the three roads running west from the state highway, which follows the railroad in this region.

Farther west and too remote from railroad to have any present commercial value, are the immense marble deposits of the Marble Mountain region in T. 43 and 44 N., R. 12 W. Kings Castle or Marble Mountain is 7396 feet high and it and other peaks nearby show tremendous bodies of marble, accessible only by trail. Other deposits are known in the vicinities of the small towns of Etna Mills, Fort Jones, and Callahan in the gold mining districts not on a railroad. One large marble deposit is 3 miles from Etna Mills, on the Sawyers Bar road.

Electro Lime and Chemical Company, Inc., C. J. Montag, president, 536 Southeast Sixth Avenue, Portland 14, Oregon, is working a limestone deposit on the Sisto Mazzuchi land, 3 miles west of Gazelle. Limestone is hauled to Gazelle, where a crushing and screening plant was put in operation in 1947. Shipments of 200 tons of agricultural limestone were being made daily, and 125 tons of "carbide rock" was being sent out weekly late in 1947.

Hathaway limestone quarry (formerly Wurst and Majors) in sec. 9, T. 41 N., R. 8 W., M. D., last reported production in 1929. The limestone was ground and sold for local agricultural use. The outcrop covers about 2 acres, in McConnahue Gulch.

Mount Shasta Lime Company holdings include 460 acres in patented and about 300 acres in unpatented claims in sec. 7, T. 42 N., R. 6 W., sec. 12, T. 42 N., R. 7 W., M. D., and others nearby. Jason Chastain, Gazelle, began work here about 1925 and he and H. A. Craig have held the claims since. A vertical kiln with a capacity of 7 tons, burning wood fuel, was erected and small tonnages of lime were produced; but no sales of lime have been reported since 1930. The deposits are 4 to 5 miles by road from Gazelle.

In 1945, M. C. Lininger & Sons, Medford, Oregon, operated the property and shipped limestone for use in beet-sugar refining. No production was reported in 1946. The material is a high-calcium limestone with very little magnesia or iron oxide, as indicated by the following analyses made by Abbot A. Hanks, Inc., furnished through the courtesy of C. J. Montag & Sons, 317 Railway Exchange Building, Portland, Oregon.

	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	P	Ignition loss
Lab. no. 70038	1.17	0.10	0.48	54.63	trace	.008	43.07
Lab. no. 70039	0.63	0.09	0.31	54.92	0.01	.007	43.32

The following list gives the locations of many limestone and marble deposits that have been mentioned in previous reports of the Division of Mines. Most of them have never been worked.

Sec. 24, T. 40 N., R. 9 W., M. D. (old lime kiln)
Sec. 17, T. 43 N., R. 9 W., M. D. (old lime kiln)
Sec. 18, T. 46 N., R. 9 W., M. D. (marble)
Sec. 6, T. 41 N., R. 9 W., M. D. (marble)
Sec. 32, T. 42 N., R. 9 W., M. D. (marble)
Sec. 8, T. 17 N., R. 8 E., H. (marble)
Sec. 13, 24, T. 47 N., R. 8 W., M. D.
W.½ T. 41 N., R. 8 W., M. D.
Secs. 27, 34, T. 42 N., R. 8 W., M. D.
Secs. 35, 36, T. 43 N., R. 8 W., M. D.
Secs. 1, 12, 13, 14, T. 42 N., R. 7 W., M. D.
N.W.¼ T. 42 N., R. 7 W., M. D.
Secs. 6, 7, T. 42 N., R. 6 W., M. D.

Solano County

From 1860 to the late eighties natural "cement rock" was quarried from the hillsides in and bordering the town of Benicia, and the cement made from it was used in rather large amounts in San Francisco.

The manufacture of portland cement began in 1902 at the plant of Pacific Portland Cement Company at Cement, about 3 miles northeast of Fairfield. For a few years the supply of limestone for the plant came from travertine deposits near the plant, but as these were being used up rapidly, with increased plant capacity, it became necessary to bring limestone by rail from the company's Mountain quarries near Cool, El Dorado County. The latter deposits supplied most of the limestone used at the plant from 1910 until 1927, when the cement plant was closed down and dismantled.

The major use of the travertine was in making cement; however, it was used prior to 1900 for smelter flux at Selby lead smelter, and for road metal and concrete aggregate.

Analyses of travertine and clay from Solano County, and the portland cement made from them

	Travertine 1	Travertine 2	Clay 1	Clay 2	Portland cement 1	Portland cement 2	(Pacific Portland Cement Co.)
SiO_2	1.21	1.25	58.25	58.65	22.25	22.55	
Al_2O_3	0.70	1.00 (Al₂O₃ + Fe₂O₃)	18.56	18.25	7.65	7.25	
Fe_2O_3	0.50		7.35	7.35	3.35	3.50	
CaO	53.62	53.65	3.10	2.15	62.85	62.60	
MgO	0.44	0.55	1.28	1.15	0.78	1.20	
Na_2O, K_2O			2.35	2.05	0.69	0.85	
SO_3	0.11		0.45	0.50	1.34	1.30	
Ignition loss	42.98	43.40			1.00	0.75	(Mostly CO_2)
H_2O			8.55	10.00			

Analyses numbered 1 from U. S. G. S. Bull. 522, 1913.
Analyses numbered 2 from California State Mining Bureau Bull. 38, 1906.

Onyx Marble

At Tolenas Springs, 6 miles north of Fairfield, spring deposits of calcium carbonate were worked on a small scale prior to 1926. The deposits have been known since early days, having been mentioned by Whitney (65), Irelan (88), Watts (90), Crawford (96), Laizure (27), and G. A. Waring (15). This stone is generally light colored and translucent, but some of it resembles resin before polishing, and shows close banding. While it takes a high polish and yields an attractive product, it has been found in only comparatively small pieces, and is rather cavernous so that it could be used only for small objects.

Similar stone has been mentioned as occurring in parts of the travertine beds which were quarried for use in portland cement.

Natural-Cement Rock

Natural-cement rock is argillaceous limestone, sometimes called hydraulic limestone. It was at one time widely used, both before and after the advent of portland cement, in Europe and this country. In late years, however, it has been produced only in limited areas where it can be cheaply mined and burned and used locally. It contains limestone,

silica, iron oxide and alumina in proportions which permit burning it to cement without adding other minerals. It does not require as high temperature as portland cement and does not clinker. According to Eckel (28), such natural material carries from 10 to 22 percent SiO_2 and 4 to 16 percent Al_2O_3 and Fe_2O_3 and may carry considerable $MgCO_3$ and 50 to 80 percent $CaCO_3$. When the magnesium content is not too high, such natural-cement rock may be brought to the proper composition to be used for portland cement.

The production of ''natural'' or ''Benicia cement'' began at Benicia, Solano County, in 1859 or 1860, and continued for many years. The material was mined in the hills adjoining the town. It occurs irregularly but was reported over several miles and in considerable quantity. The cement was used in San Francisco where many brick buildings were being built at the time and was also used a good deal for making drainage and water pipes. In 1867 it was accepted for use in a sea-wall at San Francisco by the State Harbor Commissioners (Browne, J. R. 68, p. 245). This was planned to be several miles long, and was expected to require ''many thousand tons of cement''. The Benicia product apparently set well under water in a very short time. A total of 130,000 barrels was also used in building the city hall in San Francisco (Crawford, J. J. 94, p. 381). Operation of the quarry in sec. 33, T. 3 N., R. 3 W., (partly in the town of Benicia) and of the cement plant, ceased by 1890 or earlier; there is no statistical record of the production.

Sonoma County

Lime was burned first in Sonoma County in the eighties on a ranch on Little Sulphur Creek north of Geyserville, and production was carried on irregularly until 1907. Some output was again reported from the same locality in 1937. So far as could be learned, there has been no recent activity, in fact no work except in the one case noted, on any limestone deposit in the last 20 years.

Black Ranch deposit is 6 miles north of Geyserville on Little Sulphur Creek on the old land grant called Rancho Caslamayomi. It was described in old reports of the State Mining Bureau (Irelan 88, p. 633; Aubury 06, pp. 93-94) as being in the form of large ''boulders'' of limestone, the largest 150 feet long by 70 feet wide and outcropping 30 feet above the enclosing chert. It is a hard, compact drab-colored limestone. The following analysis is said to have been made by Thomas Price (Irelan 88):

	Percent
$CaCO_3$	95.20
SiO_2	1.27
Al_2O_3 and Fe_2O_3	0.43
Oxide of manganese	0.18
Magnesia loss	1.32
Water	1.60

A continuous kiln of 50 barrels daily capacity using oak wood for fuel was used to burn the limestone.

Healdsburg Marble Company located claims years ago on a limestone deposit in secs. 1 and 2, T. 9 N., R. 12 W., M. D., about 20 miles west of Geyserville. It is a hard compact stone, colored red, cream, and white but no analysis is available. Though said to be of good size, no work has been done upon it.

Kohlman Gulch, on the coast just northwest of Fort Ross, was mentioned by W. L. Watts (93, p. 463) as the site of a deposit of pulverulent limestone. This gulch, (wrongly called Coleman by Watts) was examined for a length of 1½ miles upstream from the shore-line but only meager evidence of limestone was found. The gulch carries a torrential stream in the rainy season and debris may have covered the outcrops he mentioned.

On the *Purviance Ranch,* (formerly Ward Ranch) 3½ miles west of Healdsburg, some small outcrops of limestone were found over 20 years ago (Laizure, 26a, p. 336). No work has been done since 1926. The following analysis was said to have been made in 1906 by the late Thomas Price, San Francisco chemist:

	Percent
$CaCO_3$	93.45
$MgCO_3$	1.22
Ferrous carbonate	1.13
Alumina	1.96
Manganese oxide	0.18
SiO_2	1.59
Organic matter	0.28
Loss and undetermined	0.23

Trinity County

Due to distance from railroads of most of Trinity County, there has been little development of the non-metallic minerals and there has never been any detailed investigation of limestone deposits, although these are known to occur in several places. Gold has been the principal mineral product, except in the extreme southwest corner, where the only railroad touching the county passes near an old copper mine which has made considerable production.

Some lime was burned for local use from a deposit in sec. 21, T. 33 N., R. 9 W., M. D., and from another at the head of Oregon Gulch in sec. 3, T. 33 N., R. 10 W., M. D.

Lenses of coarsely crystalline limestone are common in the Abrams schist, and in the Chanchelulla formation in the eastern part of the county, 50 miles or more west of the railroad. In the region along the South Fork of Trinity River a series of limestone lenses once thought to be Devonian extends for many miles from the head of the river to Humboldt County near Willow Creek. The most accessible of these, in Humboldt County, are 33 miles from the nearest railroad point. Another similar belt lies a little east of the first, and a third series is reported still farther inland, in Paleozoic rocks.

Tulare County

Situated about midway between the population centers of San Francisco Bay and the Los Angeles area, and lying partly in the rich and well populated San Joaquin Valley, Tulare County has large deposits of limestone within reasonable distances of existing railroads. It could supply the valley territory from Merced to Bakersfield. At present, there is no active limestone property in the county, although at one time three deposits were worked. The use of limestone in Tulare County for soil treatment has apparently ceased, while gypsum and fertilizers are widely applied. A sugar refinery, now idle, once used local limestone and some ground limestone was also marketed for use in oil-well mud.

Part of Tulare County north and east of Three Rivers, is in Sequoia National Park, and no limestone deposits have been visited inside the park boundaries (although such deposits do occur there), as mining is not generally allowed in such parks, except upon land that was already privately owned at the time the park was established. Several of the limestone deposits within the boundaries of this park are indicated on the map showing the locations of deposits in the county, and it will be noted that in general those within the park are farther from railroad than the many privately owned deposits in other parts of the county.

Most of the deposits seen are roof pendants, more or less altered by contact metamorphism especially in their lower sections. In some cases the metamorphism has been extensive enough to make selective mining necessary. The country has been subjected to a long period of erosion, during which the sedimentary and metamorphic rocks, including limestone and marble, have been in large part removed, leaving residual deposits, typically covering hills or mountains of granitic rock, and pierced in their basal sections by a great variety of intrusives, ranging in composition from ultra-basic or lamprophyric rocks to aplite which represent the later stages of the great Sierra Nevada batholith.

Cordell Durrell (40, 43) has discussed the geology of a small part of the county, in the vicinity of Lemon Cove and Three Rivers and Jenkins (43) has described tungsten mines and prospects in the same region. Although these tungsten occurrences are associated with limestone, and may have possible commercial value, they are mostly so far from railroads that the limestone could not be marketed at a profit. The limestone bodies with scheelite are also often too small to be of interest to possible users. The map accompanying the present report shows the location of limestone deposits in the county including the larger and more accessible shown by Durrell, but only those deposits deemed to have commercial possibilities because of their size and location are described.

The geology of much of the county has not been shown on the state geologic map. Although the eastern portion is a part of the Sierra Nevada, the limestone occurrences differ from those in the Mother Lode counties. They are in part Triassic and in part Paleozoic, and do not show the uniformity in character or in degree of metamorphism that is noted farther north. This may be due to the fact that in Tulare County the surrounding rocks have been less resistant to erosion so that denudation of the batholith of the Sierra Nevada has proceeded far enough to expose contact zones not yet uncovered in the Mother Lode region.

Blossom Peak limestone is owned by Pacific Portland Cement Company, 417 Montgomery Street, San Francisco, and is in SW$\frac{1}{4}$ sec. 25, T. 17 S., R. 28 E., 1 mile southeast of Three Rivers and 9 miles by road from the terminus of Visalia Electric Railroad.

This is part of a large roof pendant of limestone and contact metamorphic rocks derived from it, occupying most of section 25 and small parts of adjacent sections. The small mountain called Blossom Peak rises steeply from the road level (900 feet elevation) to 1600 feet within this quarter-section. The decomposed rock forming the floor of the pendant outcrops in limited exposures 15 feet above the road level. It appears to have been basic igneous rock, and rather fine grained. An old lime kiln was operated here, about 300 feet northeast of the southwest corner of section 25, and limestone for it was quarried on the slope nearby. This

quarry face, 85 feet wide, is diagonal to the strike and exposes an actual width of about 50 feet. A small marble quarry was also operated by *Alles & Connor* a short distance west some years ago. No work is going on at present.

In ascending the peak from the south, the outcrops seen were limestone with some siliceous layers, and the summit is limestone; but the continuity of exposures is interrupted by soil-covered benches, possibly underlain by strips of softer limestone. The deposit has a frontage of half a mile along the road on the south side, from west to east. If a depth of 50 feet of limestone is assumed over only 80 acres of the 160, there would be over 10,000,000 tons available.

The following also own land in sec. 25, T. 17 S., R. 28 E., on which limestone occurs: *Noel Britten,* N½; *Daniel Alles,* SE¼ SE¼; and *Byron Allen,* all of SE¼ except SE¼ SE¼.

A general grab-sample taken at intervals on the south slope in the southwest quarter of the section from the vicinity of the old lime kiln to the summit gave the following analysis, indicating what might be obtained from selective mining:

	Percent
Insoluble	6.10
Ferric and aluminic oxides	0.54
Calcium carbonate	92.43
Magnesium carbonate	0.90
	99.97

An analysis of a sample designated as "Mt. Blossom siliceous lime" in a report made years ago by Sill & Sill, Los Angeles engineers, indicated 44.7 percent $CaCO_3$, 44.8 percent SiO_2, 0.4 percent Fe_2O_3, and Al_2O_3, balance not stated. This was taken for use in a report on what was then called the Britten limestone deposit, and included land in other parts of the section, before the sale of the southwest quarter. East of Blossom Peak, silicification of the limestone has been much more pronounced and the more resistant rock rises to an elevation of 2500 feet. In the southeast quarter near the road and the granitic contact, metamorphic action was also noticeable, with the development of some calcium silicate, but not in sufficient amount to be of commercial importance, so far as seen.

The Blossom Peak limestone in the SW¼ sec. 25 as exposed on the surface is coarsely crystalline, gray to light gray, loosely bonded and makes a great deal of fines, in the parts not subjected to intense contact metamorphism. As noted before, some marble was produced years ago on the west slope, and in the more siliceous bands to the east the stone is fine grained and tough.

Boydston Bros. This deposit is 9 miles southeast of Porterville, near Worth (Franke, H. A. 30, pp. 444-445). There is no record of any production in recent years from this property. The limestone is reported to be of good grade, and it is said it was once hauled to a plant at Worth.

Britten Limestone Deposit. Address Noel Britten, Three Rivers. Herbert A. Franke (30, p. 445) in his report on Tulare County, briefly mentions this deposit, and gives several analyses of samples, some of which are from holdings now under other ownership. The N½ sec. 25, T. 17 S., R. 28 E., M. D., is assessed to Noel Britten and contains lime-

stone which is more or less siliceous and probably similar to that described under Blossom Peak, which is in the southwest quarter of this section. The limestone on this section is low in magnesium and by sorting or selective mining, high-calcium stone could be had.

The following analyses of limestone samples from this property were quoted by Franke (30, p. 445) as having been taken from a report by Sill & Sill, Los Angeles:

Location	*Percent $CaCO_3$*	*Percent $MgCO_3$*	*Percent Fe_2O_3 Al_2O_3*	*Percent SiO_2*
Britten Peak	98.9	Nil	Trace	0.7
Britten Peak, next to schist	93.4	Nil	0.3	6.2
Fort Hill	99.8	Nil	Trace	0.12

Cortner Group. This deposit, on a stockraising homestead 2 miles southeast of Eshom Creek Camp in T. 15 S., R. 28 E., M. D., was not visited because it is about 22 miles from a railroad. Judging by a sample, it is similar to the Blossom Peak limestone. The sample is a white, coarsely crystalline stone. No work has been done upon it and possibly three-quarters of a mile of road would be needed to reach it.

Devil's Thumb Claims. This group of claims, in secs. 2, 3, 10, 11, and 14, T. 23 S., R. 30 E., M. D., was located years ago by A. P. O. Crabtree and others, Porterville. It is about 22 miles by road from the nearest railroad, including 4 or 5 miles of unimproved road. So far as known, the claims have not been developed.

Gill Ranches are owned by Will, Fred, Emmet, Roy, Ralph, and Adolph Gill. These ranches comprise several thousand acres of grazing land, containing a number of limestone deposits. Among them the following are the more accessible.

In sec. 5, T. 20 S., R. 28 E., M.D., southeast of the Simons deposit, and 6 miles by road from the Visalia Electric Railway, there is an outcrop of limestone on which no work has been done. It is dense, hard, finely crystalline and dark gray to black in color. A little farther southeast there is a smaller outcrop. Both are on small hills and the exposures are not sufficient to give a definite idea of possible tonnage, but they are similar geologically to the Simons deposit and superficially, at least, are smaller. A sample from the larger outcrop gave the following analysis:

	Percent
Insoluble	0.99
Ferric and aluminic oxides	0.64
Calcium carbonate	97.13
Magnesium carbonate	1.21
Total	99.97

Another deposit in sec. 13, T. 21 S., R. 28 E., was mentioned in a former report (Franke, H. A. 30, p. 445) as being on land belonging to Fred Gill. A limestone deposit on land in this section now assessed to Pacific Portland Cement Company, but formerly part of the Holdridge Ranch, has been described herein under the name Holdridge, to which reference should be made, as any limestone on adjacent land would undoubtedly be similar in composition to the latter.

In sec. 12, T. 22 S., R. 28 E., 8 miles southeast of Porterville, there is reported to be a deposit of white, coarsely crystalline and loosely bonded limestone 300 to 500 feet wide and 1500 feet long.

Holdridge deposit is owned by Pacific Portland Cement Company, 417 Montgomery Street, San Francisco. It contains 115 acres in N$\frac{1}{2}$ and SE$\frac{1}{4}$ sec. 13, T. 21 S., R. 28 E., M.D. The railroad is 1 mile south.

This deposit is a partly eroded roof pendant showing contact metamorphism and the intrusion of dikes and plugs ranging in character from fine-grained granite and aplite to dark brown or black lava. The latter rocks are fresher than the dark granitic rock forming the basement on which the limestone rests. The deposit is on a hill and extends, with several interruptions, from an elevation of 870 feet (aneroid) where it rests on the basement rock, to the height of 1175 to 1250 feet (aneroid) where black lava has broken out, forming the summit between limestone remnants. In places, as between 950 and 1080 feet elevation on the west end, the limestone has been completely eroded. The intrusives, the erosion, and the probable irregularity of the basement on which the limestone rests, would prevent any definite calculation of possible tonnage without more prospecting, but probably several hundred thousand tons should be obtainable by selective mining.

On the east side of the deposit at 1070 feet elevation an adit 45 feet long is in limestone which becomes harder at the face. At 1000 feet elevation S. 45° E. a short distance from this, there is another adit possibly 200 feet long which was not fully examined because of poor air. For 50 feet it crosses a contact zone, then traverses white and light-gray coarse crystalline limestone for about 70 feet. There a black dike occurs.

Some 250 feet west and 15 feet lower, is a quarry 45 by 70 feet with a face 40 feet high from which a few thousand tons has been produced. The limestone is white to black mottled, coarsely crystalline, and rather friable where exposed to the weather. The following analysis is of a sample taken selectively from different openings.

	Percent
Insoluble	0.50
Ferric and aluminic oxides	0.32
Calcium carbonate	94.60
Magnesium carbonate	4.54
Total	99.96

James marble deposit is mentioned in Bulletin 38 (Aubury, L. E. 06, p. 108) as ''a deposit of dark gray marble, claimed to be suitable for building purposes; located 8 miles southeast of Porterville on the road to the Tule River Indian Reservation''. So far as known, it has been idle in recent years.

Grover Johansen, Route 1, Box 98, Corcoran, has sent to our laboratory a sample of blue limestone reported to occur in a deposit near California Hot Springs, 20 miles by road from the Santa Fe Railroad.

Kaweah Quarries and *Kaweah Lime Products Company:* see Lemon Cove deposit.

Lavelle deposit is located in N$\frac{1}{2}$ SW$\frac{1}{4}$ sec. 30, T. 17 S., R. 29 E., M.D. Owners are Ruth Gratto, Jesse Lavelle, and Betty White. This deposit, 2 miles east of Three Rivers, is said to have been the source of much of the limestone formerly burned by Lavelle in an old kiln near the South Fork of Kaweah River.

The following analysis of limestone from ''Lavelle Quarry'' is quoted from a report by Sill & Sill, Los Angeles (Franke, H. A. 30, p. 445):

	Percent
$CaCO_3$	98.8
$MgCO_3$	nil
Fe_2O_3 and Al_2O_3	trace
SiO_2	0.8

Lemon Cove deposit (formerly called *Kaweah Quarries* and *Kaweah Lime Products Company)* is in NE¼ sec. 35 and NW¼ sec. 36, T. 17 S., R. 27 E., M.D., 2 miles by road from Lemon Cove and half a mile from the terminus of Visalia Electric Railway (Southern Pacific Company). The property has not been a producer since 1932, and the crushing plant and buildings are gone. Ownership was not readily obtainable at the assessor's office but a tenant on the plant site pays rent to Morgan Keaton, Route 1, Box 658, Fairoaks, California.

This has been the most extensively worked limestone deposit in the county. The limestone is in part interbedded with shale and ancient schist, has been intruded by dikes and subjected to contact metamorphism with the development of marble and siliceous bands. It covers the southwest slope of hills rising from 650 to 1035 feet (aneroid) elevation, along a frontage of about a third of a mile. Four quarries and some minor openings were examined. The principal quarries are: Northwest, 75 feet wide by 135 feet long, and 45 feet high at face; Lower East, 40 feet wide by 350 feet long and nearly 100 feet high at face; and Upper East, 50 feet by 150 feet and 50 feet high at face.

Because of the varying degrees of metamorphic action, the limestone ranges from pure white coarse crystals to fine-grained, hard and compact marble, varying in color from white to black.

The following analysis by Hanks is of a general sample from the various quarries.

	Percent
Insoluble	11.80
Ferric and aluminic oxides	0.79
Calcium carbonate	83.01
Magnesium carbonate	4.39
Total	99.99

Moorehouse Creek limestone deposits are owned by Riverside Portland Cement Company, 621 South Hope Street, Los Angeles. They include the Bluff, Rufus D. Morris, Mammoth, Jumbo, Bluff No. 2, Great Western, Travertine, and South Side patented placer claims, 997.59 acres, and possibly other unpatented claims in secs. 29, 30, 31, and 32, T. 20 S., R. 31 E., M.D. Springville on the Southern Pacific Railroad is 13 miles west by road.

These deposits are so large that a great deal of time would be required to examine them and take proper samples. So far as known the only work done was that required for patent. The claims extend from the southwest corner of section 31 northward for 1¾ miles and for 1½ miles east and west. The South Fork of Middle Fork of Tule River and the Springville-Camp Nelson road cross the claims, which extend from an elevation of 3700 to 5500 feet or more.

The deposits vary from spring deposits of travertine to high-grade limestones and siliceous marbles. Parts of the claims are covered by brush and timber. Two mountains form conspicuous parts of the holdings. The

smaller is on the west side of Moorehouse Creek near the center of S½ sec. 30, and near the line between Great Western and Bluff placer mines. A short adit has been driven near the creek. The stone here is in part white and coarsely saccharoidal, and in part is white banded with gray and not so sugary in texture. A sample taken here gave the following analysis:

	Percent
Insoluble	0.65
Ferric and aluminic oxides	0.34
Calcium carbonate	93.86
Magnesium carbonate	5.14
Total	99.99

The other (and much higher) mountain is a mile east of the first and occupies a large part of section 29, of which 340 acres is covered by three of the patented claims. It reaches 5500 feet elevation on the claims, and is part of one of the largest undeveloped limestone belts in the state. The country rock is granite and schist and there has been considerable metamorphism, with formation of marble and silicification of the limestone on the flanks of the belt. The geology of the region has not been worked out, but it is part of the Sierra Nevada and the limestone may prove to be either Triassic or Carboniferous.

The following analysis was made of a grab-sample taken near the southwest corner of the Rufus D. Morris claim in order to show the general character. Near the surface the limestone is gray, medium to fine crystalline, rather sugary and easily broken; but in part is black, tough and slaty.

	Percent
Insoluble	5.19
Ferric and aluminic oxides	1.10
Calcium carbonate	89.45
Magnesium carbonate	4.24
Total	99.98

Oat Canyon Limestone. This title has been used in a past report (Laizure, C. McK 23, p. 529) to refer to deposits described herein under *Simons limestone deposit* and *Gill Ranches.*

Simons limestone deposit is in the SE¼ sec. 6, T. 20 S., R. 28 E., M.D., 6 miles by road from the nearest railroad and 9 miles east of Lindsay. It is assessed to E. J. Simons, c/o General Machinery Company, Spokane, Washington. It has been formerly known as the *Abramson and Bode, Valley Lime Company,* and *Oat Canyon deposit.*

This deposit was last productive in 1932 and the limestone is said to have been used for sugar refining and in steel mills. Some lime was burned also in kilns near the railroad 3 miles southeast of Lindsay. It lies on a hill and has an exposed thickness or depth of 180 feet, elevation 1220 to 1400 feet. The outcrop extends for 800 feet in length northwest, with a width of 180 feet. The elevation decreases to the southeast. The country rock is schist and shale, and in the quarry floor little hummocks of shale are exposed, containing a few rotten boulders of sandstone. In one place, a layer of limestone 2 feet thick is interbedded with shale.

The quarry is 75 feet wide by 135 feet long with a maximum height of nearly 200 feet. Rock was lowered in cars on a gravity tramway to a bin near the foot of the hill and hauled to the railroad near Tiffin.

In 1930, a plant near the railroad was reported as being operated on limestone from this deposit, by Universal Silicate Stucco & Lime Products Company, but this company was not listed as a producer in statistics published by the Division of Mines. There is at present a good-sized building near the railroad which is said to belong to the owner of the quarry and to contain some machinery, but there is no equipment at the quarry.

This limestone is a dense, fine-grained stone varying in color from dark gray to black. A sample was taken across the deposit, including the quarry. The analysis made by Abbot A. Hanks, Inc., was as follows:

	Percent
Insoluble	0.80
Ferric and aluminic oxides	0.76
Calcium carbonate	94.58
Magnesium carbonate	3.86
Total	100.00

Limestone in Kernville Quadrangle

Upon a map prepared in connection with a report on the geology of Kernville quadrangle Miller and Webb (40) have mapped large surface areas of limestone as follows, all being in Tulare County:

Parts of secs. 24, 25, T. 22 S., R. 32 E.
Parts of secs. 19, 30, T. 22 S., R. 33 E.
Parts of secs. 1, 11, 12, 13, T. 23 S., R. 32 E.
Parts of secs. 6, 7, 18, T. 23 S., R. 33 E.

These deposits are mostly on the east side of Kern River in mountainous country at elevations ranging from 4000 to over 6000 feet, and in a region devoid of roads except for the one following Kern River northward from Kernville to Fairview. The distance to railroad in this direction is prohibitive. On the west, the nearest roads are those on the Tule River Indian Reservation, and the highway passing California Hot Springs, each about 10 miles away and each about 20 miles from the railroad.

This limestone has been placed in the Kernville series of metamorphic rocks, and its age has not been proven because of a lack of fossils or other positive evidence. The authors of the above paper, however, incline to the belief that the Kernville series is probably equivalent to the Calaveras (late Paleozoic) on the basis of lithologic similarity.

The marbles are described as "nearly everywhere crystalline, calcitic, white to bluish-gray, thick-bedded, fine to moderately coarse-grained and almost invariably fetid. Beds of white marble, ranging from a few to several feet in thickness are associated with bluish gray and banded white crystalline limestone."

Tuolumne County

Considering its extent and its potential importance, the great series of deposits in Tuolumne County appears to have received comparatively little attention from geologists. The Big Trees folio of the U. S. Geological Survey does not show a single analysis of the stone, and makes no reference to the differing character of the limestone in different beds. It is an interesting fact, brought out by sampling in connection with field work

for this report, that wide beds of high-grade stone, ranging from high-calcium, low-magnesium limestone to nearly true dolomite, occur close together in different parts of the district. A detailed study would probably bring out many interesting facts about this greatest of northern California's limestone accumulations. The period over which deposition extended must have been a long one, but it is doubtful if its length could even be estimated approximately because of the amount of folding that has probably gone on and the obliteration of fossils and bedding by the pressure exerted, which has nearly everywhere changed the limestone to marble.

While there are many hundreds of acres of land in and around Sonora, Columbia, and Springfield where limestone and marble have been exposed, much of this land is in residence or farm properties having value that would prevent consideration as sources of limestone. These are not covered in the present report, in which the effort has been made to give a comprehensive idea of those parts of the main limestone belt which are on or near good roads within 10 miles of the railroad.

The district has been noted particularly for the production of marble but the last of the quarries was closed down several years ago and marble-working equipment has been removed from both quarries. There is an abundance of high-grade marble in this county which takes a good polish and has been shown to excel in physical properties many of the marbles which are brought long distances for use in the Pacific Coast market. The quarrying, cutting, and polishing of marble are expensive, and the percentage of waste is always high. The marketing of this waste is an important item to the marble producer, and if he has facilities for selling it or converting it into a salable product, this may help him to stay in business.

Baxter marble quarry was 3 miles northwest of Sonora. It has not been active during the past 30 years.

Bell marble quarry: see Bell Columbia marble quarry.

Bell Columbia Marble Quarry. The quarry property and equipment upon it, in the town of Columbia, were purchased several years ago by Equipment Sales Company, 679 Bryant Street, San Francisco. All equipment and machinery have been removed.

Quarrying of marble on this land was started in December 1918 and continued at intervals for over 8 years. Although the equipment and improvements were substantial, having an assessed valuation of $38,000 the operations were hampered by lack of marble saws and a polishing plant. An effort was made to finance the erection of such a plant in Alameda County by the sale of stock, but this did not meet with success.

Rough blocks of marble weighing 6 to 14 tons each were broken out by jackhammers and plugs and feathers and were shipped to San Francisco and Oakland firms. The product varied from pure white to dark blue-veined, and from fine to medium-coarse crystal size. The series of analyses which follow showed very low contents of silica, alumina, and iron oxide for a marble, and a magnesia content ranging from a trace to about 16 percent. The weight is 169 pounds per cubic foot and the compressive strength is claimed to be about 50 percent greater than that of Alaska, Vermont, and Italian marbles. In 1920, the known area of marble in this deposit was claimed to be 350 by 700 feet but later operators

claimed more. The depth is probably several hundred feet and much greater than it would be practicable to work. So far, the pit is about 40 feet deep.

This marble was used before 1928 in San Francisco in the interior of the 22-story Standard Oil Building, in the Golden Gate Theater, Loews Warfield Theater, and the Metropolitan Life Building.

The quarry is 5 miles by paved highway from the Sierra Railway at Sonora. Electric power is available. The following analyses were reported by the company as having been made in 1923 by the George A. James Company:

	No. 1	*No. 2*	*No. 3*	*No. 4*	*No. 5*
Water and volatile	0.20%	0.20%	0.20%	0.20%	0.20%
Silica	0.20%	0.15%	0.20%	0.65%	0.55%
Alumina	0.18%	0.90%	1.30%	0.80%	0.20%
Iron oxide	trace	0.70%	0.35%	trace	0.60%
Sulphates	none	none	none	none	none
Magnesia	8.30%	13.70%	13.70%	8.32%	trace
Lime	45.40%	38.90%	38.40%	45.8%	54.9%
Carbonic acid	44.90%	45.40%	45.40%	44.8%	43.2%
Compressive strength	24,890 pounds per square inch.				

The writer took a sample across a width of 300 feet of medium-coarse crystalline light-gray marble of uniform appearance and the report of analysis made by Abbot A. Hanks, Inc., on this was as follows:

Insoluble	*Fe and Al oxides*	*$CaCO_3$*	*$MgCO_3$*
0.40%	0.37%	94.7%	4.1%

G. Bordoli and Bros. quarry is about a mile north of Sonora close to the Columbia road. Several years ago this was worked in a small way, the pure white marble being crushed in a rockbreaker to about 1-inch size for use in terrazzo. No production has been reported recently.

Childress Ranch is owned by O. D. Childress, R.F.D. 1, Sonora. This is in secs. 20 and 29, T. 1 N., R. 15 E., M.D., 5 miles by road south of Sonora. It is a little northwest of Murphy Bros. ranch where a sample was taken (see analysis, post) and the limestone is undoubtedly of the same quality. The deposit may be traced for a width of 650 feet from east to west across the ranch near the line between sections 20 and 29 and for a quarter of a mile in length. The land has an elevation of about 1600 feet but the deposit is too nearly flat to permit opening a pit to any depth without pumping and hoisting.

Columbia Marble Quarry. This property, which for a long time was the best known and largest marble producer in California, has lain idle for several years. It is in secs. 2 and 3, T. 2 N., R. 14 E., and sec. 34, T. 3 N., R. 14 E. Nearly all of the equipment and machinery described in our 1928 report (Logan, C. A. 28, pp. 51-53) has been sold and removed and the land on which the quarry is situated, 2¾ miles northeast of Columbia, has recently been sold to U. S. Lime Products Company. The new owners have been producing dolomite from the old marble quarry for lime.

The quarrying of marble began in the Columbia district in 1860. A mill with 100 saws and 4 polishing machines (Browne, J. R. 68) turned out many thousands of tons of marble between 1862 and 1866. Then the erection of similar plants in San Francisco, and the importation of Italian and Vermont marble put the California quarries out of business, as the

foreign stone could be brought thousands of miles by ship to the Pacific Coast for less than the cost of transporting California marble from quarries 150 miles from market. For quite a long time the California marble quarries were limited to supplying local needs in nearby areas where foreign stone could not compete, but Columbia marble appeared in San Francisco in 1878, and in 1891 Columbia Marble Company was established. With the building of the Sierra Railway of California, it became possible to get cheaper freight rates and the company continued under the superintendence of W. D. Bannister until his death.

The new pit which was opened in 1921 is $2\frac{3}{4}$ miles northeast of Columbia and 1100 feet from the old quarry now being worked for dolomite. Being on a steep slope it has good natural drainage and room for easy disposal of waste. Channeling machines were used in the quarry and blocks of marble weighing about 7 tons each were pulled up an inclined track to the 8 gangsaws, which sawed slabs $1\frac{1}{4}$ inches thick. These were trimmed by air chisel and put on the rubbing bed for trueing up and finishing sufficient for flooring, steps, etc. It is a 7-mile haul over good roads to the railway at Sonora.

Most of the product was a strong and durable white dolomitic marble with blue veining, although other shades to nearly black, including a beautiful buff stone with reddish veining, called Portola marble, have been quarried. At the time of our 1928 report (Logan, C. A. 28, pp. 51-53) the marble deposit was claimed to be 200 feet wide, 500 feet deep and 1 mile long, and was estimated to contain over 200,000,000 cubic feet. Later a re-organization and change of name to Columbia Marble, Inc. occurred and land holdings appear to have been reduced.

The Columbia marble is considered equal to any in the country and as regards durability and strength it is superior.

The following physical data are from a report furnished to this division some years ago.

Compressive strength	25,535 lb. per square inch.
Modulus of rupture	2,741 lb. per square inch.
Tensile strength	1,204 lb. per square inch.
Average weight	177 lb. per cubic foot.

Dunning Ranch is owned by Harry C. and Ariel J. Dunning, R.F.D. 1, Sonora. It is in sec. 20, T. 1 N., R. 15 E., M.D., $4\frac{1}{2}$ miles south of Sonora by road. It contains the north end of the large deposit described and sampled on the Murphy, Musante, and Mayhall ranches. This place was not visited, but the size and quality of deposit and the conditions under which it could be worked are believed to be similar to those on the Childress and Murphy ranches. It is about 1 mile north of where a sample was taken for analysis on the Murphy Ranch, and the limestone should be close to that sample in chemical composition.

Engler Lime Company. This company operated a generation ago in sec. 27, T. 2 N., R. 14 E., M.D., near Shaw's Flat in the region where limestone bedrock was exposed over a large area by placer mining. There has been no recent activity.

Jackson. John W. and Jessie B. Jackson, R.F.D. 1, Sonora, own 15 acres in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 27, T. 1 N., R. 15 E., 5 miles by road south of Sonora, which contain a small part of the deposit described (post) under Mayhall, Murphy, and Musante. Because of the small tonnage and the fact it lies flat, it is not likely to prove of commercial value.

Mayhall Ranch is owned by Wm. E. and Jennie Mayhall, P.O. Box 659, Sonora. This ranch covers parts of secs. 26, 27, 32, 34, and 35, T. 1 N., R 15 E., 8 miles more or less from either Sonora or Jamestown by good roads. The elevation varies from 1560 to 2040 feet.

The widest part of the large deposit crosses this ranch from west to east for about a mile and a half. On the west property line the deposit is almost certainly 2100 feet wide from north to south, but no drilling or other prospecting has been done to determine its depth. Farther east it is wider but there the topography is not favorable for cheap large-scale operation as there has been considerable transverse erosion. The part of the deposit on this ranch would yield over 500,000 tons per foot in depth. As indicated by the analyses below, the character of the stone would vary from high-calcium, low-magnesium limestone to a stone approaching a pure dolomite. It would take extensive sampling, beyond the scope of this report, to determine the extent of the different beds. Samples T3 and T4 were taken at the west property-line as a particularly favorable and extensive outcrop there is exposed continuously for about 900 feet in width, north to south, and through 150 feet vertical range. Blanket Creek has eroded its valley here on the southern side of the limestone so that some 1200 feet in width of the stone has been reduced to the valley level, is partly soil covered and could not be properly sampled. An examination of the 900-foot outcrop before sampling revealed a sufficiently marked variation to suggest the advisability of sampling two sections separately. Sample T3 represents a width of 600 feet of rather coarsely crystalline, but firm, even-textured gray to white stone on the north side. Sample T4 represents a width of 300 feet of finely granular, ''sugary'' and rather friable stone directly in contact with the 600-foot section on its south side. Samples were taken by breaking fresh chips 2 inches by 3 inches or larger, as nearly as practicable at 3 foot intervals across the widths named. The marked differences in the analyses of these samples (shown below) indicates that selection of a desired grade might be feasible. These samples were taken along the line between sections 33 and 34 and apply also to the adjoining Giacomo Musante Ranch, on the west.

Another sample, T5, was taken across 700 feet near the line between sections 26 and 35 close to the east line of the Mayhall property, where the beds of limestone are more mixed, including a layer 21 feet thick of pure white, fine-grained marble. Here, near the junction of the county road from Jamestown with the Sonora and Wards Ferry road, the deposit begins to break into several strands extending east and fingering out in steeper and less accessible country with a poor road. This road junction is 10 miles from Sonora.

Analyses by Abbot A. Hanks, Inc., November 13, 1943

	Sample T3	*Sample T4*	*Sample T5*
Insoluble	0.54%	2.28%	1.43%
Ferric and aluminic oxides	0.57%	0.91%	0.44%
Calcium carbonate	95.76%	60.77%	80.49%
Magnesium carbonate	2.84%	35.46%	17.38%

McCormick Estate: Address c/o Frank A. McPherson, Sonora. This is near the center of sec. 7, T. 1 N., R. 15 E., 2 miles south of Sonora on a good road.

Although the soil covering conceals much of the deposit except where it was exposed by early-day placer mining, the limestone is believed to extend from north to south across the land for half a mile. The sample analyzed below is from a width of 87 feet of a section believed to be 117 feet wide. Backs of 125 feet could be obtained from the level of Sullivan Creek which passes near the north end of the property. An old mine adit, reported 1550 feet long, is said to be entirely in limestone.

Analysis by Abbot A. Hanks, Inc., November 1943

	Percent
Insoluble	0.91
Ferric and aluminic oxides	0.61
Calcium carbonate	90.79
Magnesium carbonate	7.36

McLean limestone deposit is assessed to Mary Beth McEachran, P.O. Box 44, San Francisco. It contains 21.54 acres in sec. 23, T. 2 N., R. 14 E., 5 miles by paved highway from Sonora. It is a part of the great Columbia marble area where the stone was exposed by early-day placer mining. On this land, the limestone is white or light gray, fine-grained, and compact. It has been worked in a small way by hand-mining of the exposed boulders, crushing the stone in rock breakers and in a small Hardinge conical mill, screening, bagging, and shipping. The principal market is said to have been for poultry grit. The property had been idle for some time when visited.

McPherson Ranch property is assessed to Winnie McPherson, R.F.D. 1, Sonora. This 83-acre holding in secs. 7 and 18, T. 1 N., R. 15 E., adjoins on the south the McCormick Estate land (see ante) and contains the southern end of the deposit described thereunder. The limestone is undoubtedly continuous for nearly half a mile in length on this land, although partly covered by soil. Near the south end, the deposit is about 300 feet wide. The composition is doubtless similar to that shown in the McCormick analysis. Sonora railroad station is 2¾ miles north by road.

Murphy Bros. Ranch is assessed to Albert, George, and Charles Murphy, R.F.D. 1, Sonora. This holding of several hundred acres in secs. 20, 21, 28, and 29, T. 1 N., R. 15 E., extends from the Sonora-Algerine road 5 miles south of Sonora, to the Musante Ranch. The large limestone deposit extends from Curtis Creek for 11 miles eastward into the steep canyon of Tuolumne River. From Curtis Creek, through the Murphy land, the limestone has been eroded to the general level of the nearly flat country and is partly covered by soil. Here the outcrops of limestone are each usually only a few square feet in area, seldom over 1 foot high and may be as much as 20 to 40 feet apart, so that hand sampling is unsatisfactory. Possibilities for open-pit mining would be limited. Because of the soil cover, the width of the deposit and any variations in character can not be noted definitely. In appearance the limestone outcrops are white to light gray, high grade, firm textured and fine to medium crystalline. The analysis of a sample taken across a width of 540 feet and about 700 feet south of the road mentioned, on the Murphy land, shows it is very similar to the 600-foot section sampled on the Mayhall property.

Analysis by Abbot A. Hanks, Inc., November 1943

	Percent
Insoluble	0.46
Ferric and aluminic oxides	0.13
Calcium carbonate	95.41
Magnesium carbonate	3.93

Although the road from this property to Jamestown is slightly longer than that to Sonora, grades on it are easier.

Musante Ranch is assessed to Giacomo Musante et al., R. F. D. 1, Sonora. This ranch of about 500 acres in secs. 28, 33, and 35, T. 1 N., R. 15 E., is traversed for about a mile by the same limestone deposit already described, ante, under Mayhall and Murphy Ranches, between which part of the Musante holdings are situated. The limestone here is 7 miles by good road from Jamestown. On the north side of the road, in the eastern part of section 33, the limestone extends to the tops of two hills, offering opportunities for opening quarries from which large tonnages could be obtained. As mentioned under Mayhall Ranch, the deposit is probably 2100 feet wide from north to south along the line between sections 33 and 34, which here is the east line of the Musante land. The samples of which analyses are shown under Mayhall, apply to the Musante land as well, covering widths of 600 feet and 300 feet respectively and indicating marked variation in the characters of the two beds. The amount of limestone available here above the road level, assuming that it extends to a vertical depth of only 100 feet would be several million tons. No work has ever been done on it.

U. S. Lime Products Corporation, main office 85 Second Street, San Francisco. The lime plant and lime deposit 1 mile south of Sonora in sec. 1, T. 1 N., R. 14 E., have been operated many years by this company and its predecessor, Pacific Lime & Plaster Company. Recently some changes have been made in management, and the marble property formerly belonging to Columbia Marble Company, 131 acres in sec. 34, T. 3 N., R. 14 E., 3 miles northwest of Columbia, has been purchased.

The property south of Sonora covers 4000 feet along the deposit which extends southward from Columbia through the county seat, terminating about a mile south of Sullivan Creek. This is the site of the lime plant. Limestone high in calcium and low in magnesium content is produced by underground mining, using the room and pillar system. Most of the stone is handled by Eimco-Finlay loaders, and a conveyor belt has been installed recently to deliver stone from the shaft to the crushing plant. Mining has reached a depth of 315 feet. The deposit lies between walls of Calaveras (Mississipian) rocks and is cut by several dikes. For the most part, it is solid, coarsely crystalline white and light gray limestone with a small percentage of magnesia and very little silica, alumina, and iron oxide.

The stone mined from the recently-purchased land near Columbia is the dolomitic marble quarried from the old pit of Columbia Marble Company. This is much higher in magnesium carbonate than the stone south of Sonora, and is commonly called dolomite. It is hauled 8 miles in trucks to the plant. All of the marble-sawing equipment once used by the former operators has been removed from this land.

Part of the 13 vertical kilns of the old plant have been used recently for burning dolomite. Little change is reported in their operation since

the last report (Logan, C. A. 28). They are lined with three courses of firebrick and have a capacity of approximately 100 tons of lime a day.

A new rotary kiln, 6 by 120 feet, has been installed for burning high-calcium lime. This is lined with Stockton firebrick 9 inches thick at the firing end and 6 inches at the cooler end. This brick is said to last $1\frac{1}{2}$ years in the hot zone. The limestone is in this kiln about 6 hours and maximum kiln temperature is 2400° to 2800° F. The kiln is fitted with a Western Precipitation Company multi-cone dust collector and the main tall stack has been sealed off. Lime production capacity is somewhat curtailed because of the tendency of the stone to decrepitate, requiring care in regulating heat and speed. Fuel oil is used.

Besides serving the steel trade with lime, three sizes of quicklime, 16-mesh, $\frac{1}{4}$-inch, and $\frac{5}{8}$-inch, are screened. The hydrate plant produces three grades of lime hydrate, the best being marketed under the tradename of Sierra Superfine hydrate, the second as Sierra, and the third for agricultural use. A Raymond high-side roller mill is used to grind both lime and limestone. A poultry-grit plant, with elevator and shaking screens, produces turkey and chicken grits of different sizes, and chicken flour.

Great difficulty has been experienced in getting and holding a crew of men in competition with other industries which were allowed higher wage ceilings. As a result the plant has not been able to operate at full capacity.

Ventura County

During the last 20 years there has been irregular production from deposits of shell limestone on Rancho Simi, north and east of north from Santa Susana. The quarries are on hills $2\frac{1}{2}$ miles apart and 1 to 2 miles from the Los Angeles County line.

A so-called "natural-cement rock" has also been known for many years in Matilija Canyon 8 to 10 miles northwest of Ojai. Remains of an old kiln in the canyon indicate that some of the stone was burned in early days.

Argilla group of claims is in secs. 23 and 24, T. 5 N., R. 24 W., S. B., 9 miles by road northwest of Matilija, a railroad point a mile west of Ojai. A massive bed of limestone strikes east along the south side of Matilija Canyon. The following analysis was published in 1925 (Tucker, W. B. 25a, p. 240).

	Percent
Silica	16.015
Aluminum and iron oxide	5.32
Lime	42.63
Magnesia	1.119
Carbon dioxide	34.19

Gillibrand (Tapo Alto) deposit is 6 miles by road north from Santa Susana, in the northeast part of Rancho Simi. This was under lease in 1924 to Ventura County Lime & Fertilizer Company, and a small production was reported.

The deposit is of shell limestone, on the summit of Tapo Alto Mountain, at an elevation of 2400 feet. An analysis by Smith, Emery & Company, first published in 1924 (Tucker, W. B. 24, p. 97) indicated a very good grade material:

Analysis of Tapo Alto shell limestone

	Percent
CaO	54.64
CO_2	42.86
P_2O_5	0.07 to 0.33
Insoluble equivalent	2.07
$CaCO_3$	97.50

In 1929 Tapo Alto Shell & Fertilizer Company leased the deposit and produced limestone until 1935. They dug limestone with a ¼-cubic-yard gasoline shovel, and screened and crushed it in a plant having a daily capacity of 15 tons. The principal product was poultry grit in two sizes, minus 8-mesh plus 10-mesh, and minus 10-mesh. Some shipments of limestone rejected in the above process were also made for agricultural use. A sample of this material, taken and tested by the State Department of Agriculture, was found to carry 91 percent $CaCO_3$. A screening test showed 98 percent passing 40-mesh and 24 percent passing 100-mesh sieves.

Matilija claims are in sec. 19, T. 5 N., R. 23 W., S. B., 8 miles by road northwest of Ojai. The limestone outcrop is said to be 75 to 100 feet wide and to strike east for half a mile along the ridge north of Matilija Creek. It is an impure, hard blue stone probably similar in analysis to that already mentioned in the Argilla, which lies to the west. The two claims have not been developed.

Tapo Alto Shell Lime & Fertilizer Company, see Gillibrand.

Ventura Cement Company for many years held 400 acres, patented, in secs. 22, 23, 26, and 27, T. 5 N., R. 24 E., S. B., 10 miles from Matilija, on the Ojai branch of the Southern Pacific Railroad.

A deposit of gray, fine-grained limestone outcrops in two beds, 75 feet and 175 feet thick respectively, and separated by about 300 feet of shale, on the northwest side of a branch canyon which enters Matilija Canyon from the southwest. The deposit is said to be traceable westward for about half a mile into another canyon. It dips steeply south. The state geologic map (Jenkins, O. P. 38) shows this area to be covered by upper Eocene rocks. The following analyses, published in 1932 (Tucker, W. B. 33, p. 268), shows the deposit to be mainly of the type called "natural-cement rock", although selected samples have given from 93.5 to 97.86 percent $CaCO_3$.

Analyses of Ventura Cement Company's limestone

	Percent	Percent	Percent	Percent	Percent
Volatile (CO_2)	34.54	30.99	44.26	36.78	28.78
SiO_2	15.06	22.64	2.95	12.22	28.54
Al_2O_3 and Fe_3O_4	5.20	7.86	1.94	4.76	6.34
CaO	42.76	37.76	35.33	43.60	36.06
$CaCO_3$ (equivalent)	76.11	69.97	63.59	78.48	64.91

Western Lime Products Company, 6305 Yucca Street, Hollywood 28, has been the only limestone producer in the county in the past few years. They have been working a deposit of shell limestone 5 miles north of Santa Susana, on Rancho Simi. The quarry is on a hill at an elevation of 2200 feet. The product is sold for use in poultry and cattle feeds, and agricultural limestone. Partial analyses of the part of the product mar-

keted as ''oyster-shell meal,'' analyzed by the State Department of Agriculture, showed 93.76 percent $CaCO_3$ in 1942, 91.59 percent $CaCO_3$ in 1943, and 90.75 percent $CaCO_3$ in 1946. The property is claimed by the operators to contain 8,000,000 tons.

Yolo County

No limestone production has been recorded from Yolo County. Years ago, mention was made of a limestone deposit reported to be in secs. 30 and 31, T. 10 N., R. 2 W., 3 miles south of Cadenassa Station (Bradley, W. W., 16, p. 368). An anonymous report has recently been found in the Division of Mines files which is dated December 1919 and purports to give the results of a preliminary survey of materials suitable for cement manufacture in the county. The region examined is in and near Capay Valley, from the vicinity of Capay to a point east of Guinda. Several samples were analyzed, but only one was from rock in place. This was a siliceous limestone found ''south of the county road ½ mile above Capay.'' Two samples of float, one from the J. H. Cranston place and one from the Stephens Agricultural and Livestock Company land near Cranston's property line, both being above Cadenassa, were found to be of good grade limestone. The same writer also mentioned finding boulders of gray, flinty limestone in Salt Creek west and south of Cadenassa. This he thought came from property owned by E. M. Nash, and Cowell Lime & Cement Company, but a search of several hours over the land failed to show similar rock in place. This is probably the same limestone mentioned by Bradley (16, p. 368).

The deposit in place mentioned by this anonymous writer occurs as chalky limestone of marl in a series of low, flat hills along the eastern edge of the valley, and may have been a lake or spring deposit. Pliocene non-marine sediments are shown on the Division of Mines state geologic map along the east side of this valley. The higher land on both sides of the valley is occupied by older marine sedimentary rocks, principally upper Cretaceous, and in these rocks it is not unusual to find occasional small bodies of hard limestone. This is probably the explanation of the lumps and ''boulders'' of such limestone found, that could not be traced to a deposit in place.

The soft limestone may eventually have value for agricultural use.

Analyses of samples of "float" limestone, Yolo County

	J. H. Cranston	*Stephens A. & L. Co*
SiO_2	6.60%	1.40%
R_2O_3	0.60%	0.50%
CaO	50.35%	54.25%
MgO	0.70%	----
CO_2	40.90%	42.65%
H_2O and volatile	1.00%	1.10%
	100.15%	99.90%

Yuba County

The western part of Yuba County is in the Sacramento Valley, which is covered to great depths by alluvium. Most of the remainder of the county is occupied by outcrops of altered basic igneous rocks and by parts of the granitic batholith of the Sierra Nevada. These have been

almost entirely stripped by erosion of the thick mantle of older metamorphic rocks which once covered them, and which in the more southerly counties contain valuable limestone deposits. A narrow belt of Carboniferous rocks extends northwestward across the extreme eastern side of the county and three small bodies of limestone have been exposed by stream erosion where Oregon Creek and North Fork of Yuba River cross this belt. Another narrower belt of Carboniferous rocks running northwest from near Bullards Bar is not known to contain limestone.

The deposit on Oregon Creek is 2 miles west of south of Camptonville, in sec. 15, T. 18 N., R. 8 E., M. D. The others are in the steep canyon of the North Fork of Yuba River, one being on the south side of the river $1\frac{1}{4}$ miles east of the mouth of Slate Creek, and the other on the north side of the river 2 miles west of the first. All three are too remote to be considered except for local use.

BIBLIOGRAPHY

Allen, John Eliot

46 Geology of the San Juan Bautista quadrangle, California: California Div. Mines Bull. 133, pp. 9-75, 1946.

Aubury, Lewis E.

06 The structural and industrial materials of California: California Min. Bur. Bull. 38, 412 pp., illus., 1906.

Averill, Charles Volney

37 Redding field district—mineral resources of Plumas County: California Div. Mines Rept. 33, pp. 79-143, illus., 1937.

41 Mineral resources of Humboldt County: California Div. Mines Rept. 37, pp. 499-528, 1941.

Beede, J. W.

24 (and **Kniker, H. T.**) Species of the genus *Schwagerina* and their stratigraphic significance: Univ. Texas Bull. 2433, p. 17, 1924.

Boalich, E. S.

21 Monterey County: California Min. Bur. Rept. 17, pp. 156-157, 1921.

Bowles, Oliver

29 Metallurgical limestone; problems in production and utilization: U. S. Bur. Mines Bull. 299, 40 pp., 1929.

46 (and **Jensen, N. C.**) Stone: Minerals Yearbook, 1944, pp. 1238-1271, 1946.

Bradley, Walter W.

16 Yolo County: California Min. Bur. Rept. 14, pp. 367-370, 1916.

19 (and **Logan, C. A.**) San Benito County: California Min. Bur. Rept. 15, pp. 616-573, 1919.

Branner, J. C.

09 (**Newsom, J. F.**, and **Arnold, R.**) U. S. Geol. Survey Geol. Atlas, Santa Cruz folio (no. 163), 12 pp., 2 sheets illus., 3 maps, 1909.

Breyer, Frank A.

42 Pidgeon ferro-silicon process for magnesium: Chem. Met. Eng., vol. 49, no. 4, p. 87, 1942.

Brown, G. Chester

16 Kern County: California Min. Bur. Rept. 14, pp. 471-523, illus., 1916.

Browne, John Ross

68 Report on the mineral resources of the States and Territories west of the Rocky Mountains, 674 pp., California pp. 12-298, Washington, D. C., U. S. Treasury Dept., 1868.

Burchard, Ernest F.

12 Lime: Mineral Resources U. S., 1911, pt. 2, pp. 645-718, 1912.

Chesterman, Charles W.

42 Contact metamorphic rocks of the Twin Lakes region, Fresno County, California: California Div. Mines Rept. 38, pp. 243-281, map, 1942.

Clark, Bruce Lawrence

35 Tectonics of the Mount Diablo and Coalinga areas, middle Coast Ranges of California: Geol. Soc. America Bull. 46, pp. 1025-2078, 3 pls., 9 figs., 1935.

Clark, Clifton W.

21 Lower and Middle Cambrian formations of the Mohave Desert: Univ. California, Dept. Geol. Sci. Bull., vol. 13, pp. 1-7, 1921.

Clarke, Frank Wigglesworth

24 The data of geochemistry, 5th ed., U. S. Geol. Survey Bull. 770, 841 pp., 1924.

Cloudman, H. C.

19 (**Huguenin, E.,** and **Merrill, F. J. H.**) San Bernardino County: California Min. Bur. Rept. 15, pp. 775-899, 1919.

Crawford, J. J.

94 Twelfth report of the State Mineralogist: California Min. Bur Rept. 12, 541 pp., 1894.

96 Thirteenth report (third biennial) of the State Mineralogist for the two years ending September 15, 1896: California Min. Bur. Rept. 13, 726 pp. 1896.

Daly, Reginald Aldworth

09 First calcarous fossils and the evolution of the limestones: Geol. Soc. America Bull. 20, pp. 153-170, 1909.

Dana, Edward Salisbury

32 A text-book of mineralogy, 4th ed., 851 pp., 1932.

De Groot, H.

90 Inyo County: California Min. Bur. Rept. 10, pp. 209-218, 1890.

Diller, J. S.

06 Description of the Redding quadrangle, California: U. S. Geol. Survey, Geol. Atlas, Redding Folio (no. 138), 14 pp., maps, 1906.

08 Geology of the Taylorsville region, Calif.: U. S. Geol. Survey Bull. 353, 128 pp., 5 pls., 1908.

Durrell, Cordell

40 Metamorphism in the southern Sierra Nevada northeast of Visalia, California: Univ. California, Dept. Geol. Sci. Bull., vol. 25, pp. 1-118, 1940.

43 Geology of the Sierra Nevada northeast of Visalia, Tulare County, California: California Jour. Mines and Geology, vol. 39, pp. 153-168, pl. 3, 1943.

Eakle, Arthur S.

19 (and **McLaughlin, R. P.**) Mono County: California Min. Bur. Rept. 15, pp. 135-175, 1919.

23 Minerals of California: California Min. Bur. Bull. 91, 328 pp., 1923.

Eckel, Edwin C.

28 Cements, limes, and plasters, 3d ed., 1928.

33 Limestone deposits of the San Francisco region: California Div. Mines Rept. 29, pp. 348-361, illus., 1933.

Emery, Alden H.

37 Mineral fillers, in Industrial minerals and rocks (Seeley W. Mudd Series), pp. 483-492, Am. Inst. Min. Met. Eng., 1937.

Fairbanks, Harold Wellman

93 Geology and mineralogy of Shasta County: California Min. Bur. Rept. 11, pp. 24-53, map, 1893.

93a Geology of San Diego County; also of portions of Orange and San Bernardino Counties: California Min. Bur. Rept. 11, pp. 76-120, illus., 1893.

94 Geology of northern Ventura, Santa Barbara, San Luis Obispo, Monterey, and San Benito Counties: California Min. Bur. Rept. 12, pp. 493-526, 1894.

04 Description of the San Luis quadrangle, Cal.: U. S. Geol. Survey, Geol. Atlas, San Luis folio (no. 101), 14 pp., maps, 1904.

Fiedler, William Morris

44 Geology of the Jamesburg quadrangle, Monterey County, California: California Div. Mines Rept. 40, pp. 177-250, map, 1944.

Fitch, A. A.

31 The geology of Ben Lomond Mountain: Univ. California, Dept. Geol. Sci. Bull., vol. 21, pp. 1-13, 2 figs, 1931.

Forstner, William

03 The quicksilver resources of California: California Min. Bur. Bull. 27, 273 pp., illus., 8 maps, 1903.

Franke, Herbert A.

30 Tulare County: California Div. Mines Rept. 26, pp. 423-471, illus., 1930.

30a Santa Clara County: California Min. Bur. Rept. 26, pp. 2-39, illus., 1930.

Goodyear, W. A.

90 Colusa County: California Min. Bur. Rept. 10, pp. 153-164, 1890.

Hanks, Henry G.

84 Catalogue and description of the minerals of California as far as known, with special reference to those having an economic value: California Min. Bur. Rept. 4, pp. 61-397, 1884.

86 Building stones and building materials in California: California Min. Bur. Rept. 6, pt. 1, pp. 16-34, 1886 . . . California minerals, pp. 91-141.

Hazzard, John C.

37 (and **Dosch, E. F.**) Archean rocks in the Piute and Old Woman Mountains, San Bernardino County, California (abstract): Geol. Soc. America Proc. 1936, pp. 308-309, 1937.

37a Paleozoic section in the Nopah and Resting Springs Mountains, Inyo County, California: California Div. Mines Rept. 33, pp. 289-339, 1937.

Hinds, Norman E. A.

33 Geologic formations of the Redding-Weaverville district, northern California: California Div. Mines Rept. 29, pp. 77-122, 1933.

Hoots, Harold W.

31 Geology of eastern part of the Santa Monica Mountains, California: U. S. Geol. Survey Prof. Paper 165, pp. 83-134, 1931.

Hopper, Richard G.

47 Geologic section from the Sierra Nevada to Death Valley, California: Geol. Soc. America Bull. 58, pp. 393-432, 6 pls., 1947.

Hubbard, Henry G.

43 Carbon dioxide gas occurrences in Mendocino and northern Sonoma Counties: California Jour. Mines and Geology, vol. 39, pp. 301-309, 8 figs., 1943.

43a Mines and mineral resources of Santa Cruz County: California Div. Mines Rept. 39, pp. 11-52, 2 pls., 21 figs., 1943.

Huguenin, Emile

21 (and **Castello, W. O.**) San Mateo County: California Min. Bur. Rept. 17 pp. 167-179, 1921.

Irelan, William Jr.

88 Eighth annual report of the State Mineralogist for the year ending October 1, 1888: California Min. Bur. Rept. 8, 948 pp., illus., 1888.

90 Ninth annual report of the State Mineralogist for the year ending December 1, 1889: California Min. Bur. Rept. 9, 352 pp., illus., 1890.

Jenkins, Olaf P.

38 Geologic map of California, scale 1:500,000, California Div. Mines, 1938.

42 Tabulation of tungsten deposits of California, to accompany Economic Mineral Map No. 4: California Div. Mines Rept. 38, pp. 303-364, 1942.

Jenkins, William O.

43 Tungsten deposits northeast of Visalia, California: California Div. Mines Rept. 39, pp. 169-182, 3 figs., 1943.

Johnson, J. Harlan

43 Geologic importance of calcareous algae with annotated bibliography: Colorado School of Mines Quart., vol. 38, no. 1, January 1943.

Jones, William F.

11 The geology of the Sargent oil field: Univ. California, Dept. Geol. Sci. Bull., vol. 6, pp. 55-78, map, 1911.

Keenan, Marvin Francis

32 The Eocene Sierra Blanca limestone at the type locality in Santa Barbara County, California: San Diego Soc. Nat. Hist., Trans., vol. 7, pp. 53-84, 1932.

Kirkpatrick, Sidney D.

41 Magnesium from the sea: Chem. Met. Eng., vol. 48, no. 11, pp. 76-84, illus., 1941.

Kunz, George F.

05 Gems, jewelers' materials, and ornamental stones of California: California Min. Bur. Bull. 37, 168 pp., illus., 1905.

Laizure, C. McK

23 San Francisco field division—Tulare County: California Min. Bur. Rept. 18, pp. 519-542, illus., 1923.

25 San Francisco field division—Monterey County: California Min. Bur. Rept. 21, pp. 23-57, 1925.

25 San Francisco field division—San Luis Obispo County: California Min. Bur. Rept. 21, pp. 499-538, 1925.

26 San Francisco field division—Santa Cruz County: California Min. Bur. Rept. 22, pp. 8-93, illus., 1926.

26a Sonoma County: California Min. Bur. Rept. 22, pp. 327-365, illus., 1926.

27 San Francisco field division—Solano County: California Min. Bur. Rept. 23, pp. 203-213, 1927.

29 San Francisco field division—Alameda County: California Div. Mines Rept. 25, pp. 427-467, 1929.

Lawson, Andrew Cowper

02 (and **Palache, C.**) The Berkeley Hills, a detail of Coast Range geology: Univ. California, Dept. Geol. Sci. Bull., vol 2, pp. 349-450, map, 1902.

08 (with **Branner, J. C., Gilbert, G. K., Reid, H. F.,** and others) The California earthquake of April 18, 1906. Report of the State Earthquake Investigation Commission: Carnegie Inst. Washington Pub. 87, vol. 1, pt. 1, 18, 254 pp., pt. 2, pp. 255-451; atlas, 25 maps and seismograms, 1908.

14 Description of the San Francisco district; Tamalpais, San Francisco, Concord, San Mateo and Hayward quadrangles: U. S. Geol. Survey Geol. Atlas, San Francisco folio (no. 193), 24 pp., maps, 1914.

Lesesne, Sherman D.

40 Stabilization of clay roadbeds with lime: Nat. Lime Assoc., Bull. 325, 16 pp., 1940.

Lindgren, Waldemar

95 (and **Turner, H. W.**) U. S. Geol. Survey Geol. Atlas, Smartsville folio (no. 18), 6 pp., 4 maps, 1895.

Logan, Clarence A.

27 Sacramento field division—El Dorado County: California Min. Bur. Rept. 22, pp. 397-452, illus., 1927.

28 Sacramento field division—Tuolumne County: California Div. Mines and Mining, Rept. 24, pp. 3-53, illus., 1928.

36 (and **Franke, H. A.**) Mines and mineral resources of Calaveras County: California Div. Mines Rept. 32, pp. 226-364, illus., 1936.

Lowell, F. L.

16 Humboldt County: California Min. Bur. Rept. 14, pp. 391-414, 1916.

16a Mariposa County: California Min. Bur. Rept. 14, pp. 569-604, illus., 1916.

Mayo, Evans B.

34 Geology and mineral deposits of Laurel and Convict Basins, southwestern Mono County, California: California Div. Mines Rept. 30, pp. 79-88, illus., 1934.

Merrill, Frederick J. H.

16 Imperial County: California Div. Mines Rept. 14, pp. 723-743, illus., 1916.

16a San Diego County: California Min. Bur. Rept. 14, pp. 637-722, illus., 1916.

19 Riverside County: California Min. Bur. Rept. 15, pp. 522-589, illus., 1919.

Miller, William J.

40 (and **Webb, R. W.**) Descriptive geology of the Kernville quadrangle, California: California Div. Mines Rept. 36, pp. 343-378, 31 figs., pl. 2, 1940.

44 Geology of parts of the Barstow quadrangle, San Bernardino County, California: California Div. Mines Rept. 40, pp. 73-112, 18 figs., pls. 5-6, 1944.

Morey, George W.

42 Glass, in Rogers' industrial chemistry, 6th ed., vol. 1, pp. 775-813, D. Van Nostrand Company, Inc., New York, 1942.

Murray, J.

91 (and **Renard, A. F.**) Report on deep-sea deposits based on the specimens collected during the voyage of H. M. S. "Challenger" in the years 1873-1876, pp. 1-525, London, 1891.

Nelson, Richard Newman

25 Geology of the hydrographic basin of the upper Santa Ynez River, California: Univ. California, Dept. Geol. Sci. Bull., vol. 15, pp. 327-396, 1925.

28 (and **Schenck, H. G.**) Calcareous algae in Pacific coast limestone (abst.): Geol. Soc. America Bull. 39, p. 266 . . . Biol. Abstracts, vol. 4, p. 215, 1930.

29 (and **Schenck, H. G.**) Fossil calcareous algae in Pacific Coast marine formations: Pan-Am. Geologist, vol. 52, pp. 155-156, 1929 . . . (abst.): Geol. Soc. America Bull. 41, pp. 209-210, 1930.

Noble, Levi F.

41 Structural features of the Virgin Spring area, Death Valley, California: Geol. Soc. America Bull. 52, pp. 941-1000, 20 pls., 6 figs., 1941.

Oakeshott, Gordon B.

37 Geology and mineral deposits of the western San Gabriel Mountains, Los Angeles County: California Div. Mines Rept. 33, pp. 215-249, 7 figs., pl. 3, 1937.

Pabst, Adolf

38 Minerals of California: California Div. Mines Bull. 113, 344 pp., 1938.

Preston, E. B.

92 Monterey County: California Min. Bur. Rept. 11, pp. 259-262, 1892.

Reiche, Parry

37 Geology of the Lucia quadrangle: Univ. California, Dept. Geol. Sci. Bull., vol. 24, pp. 115-168, map, 1937.

Robotham, C. A.

34 Mining limestone by a caving method at Crestmore mine of the Riverside Cement Co., Crestmore, Calif.: U. S. Bur. Mines Inf. Circ. 6795, 20 pp., 10 figs., 1934.

Rook, Stephen H.

42 (and **Williams, G. C.**) Imperial carbon dioxide gas field: Summary of Operations, California Oil Fields, vol. 28, no. 2, pp. 12-33, 5 figs., 4 pls., 1942.

Sampson, Reid J.

32 Economic mineral deposits of the San Jacinto quadrangle: California Div. Mines Rept. 28, pp. 3-11, illus., 1932.

37 Mineral resources of Los Angeles County: California Div. Mines Rept. 33, pp. 173-213, illus., 1937.

40 (and **Tucker, W. B.**) Mineral resources of Mono County: California Div. Mines Rept. 36, pp. 117-156, illus., 1940.

42 (and **Tucker, W. B.**) Mineral resources of Imperial County: California Div. Mines Rept. 38, pp. 105-145, illus., 1942.

Shreve, R. Norris

45 The chemical process industries (Chemical Engineering Series), 957 pp., McGraw-Hill Book Company, 1945.

Smith, James Perrin

94 The metamorphic series of Shasta County, Cal.: Jour. Geology, vol. 2, pp. 588-612, 1894.

16 Geologic map of California, scale 1:1,000,000, California Min. Bur., 1916.

Storms, W. H.

93 San Diego County: California Min. Bur. Rept. 11, pp. 376-387, illus., 1893.

Taff, Joseph A.

35 Geology of Mount Diablo: Geol. Soc. America Bull. 46, pp. 1079-1100, 1 pl., 1 fig., 1935.

Taliaferro, N. L.

33 The relation of volcanism to diatomaceous and associated siliceous sediments: Univ. California, Dept. Geol. Sci. Bull., vol. 23, pp. 1-56, 1933.

43 Manganese deposits of the Sierra Nevada, their genesis and metamorphism: California Div. Mines Bull. 125, pp. 277-332, 20 figs., 1943.

Townsend, Robert H.

33 Method and cost of quarrying limestone at the plant of the Calaveras Cement Company, San Andreas, California: U. S. Bur. Mines Inf. Circ. 6610, 11 pp., 1933.

Trask, Parker D.

26 Geology of the Point Sur quadrangle, California: Univ. California, Dept. Geol. Sci. Bull., vol. 16, pp. 119-186, 1926.

Tucker, W. Burling

22 Redding field division: California Min. Bur. Rept. 18, pp. 729-736, 1922.

24 Los Angeles field division: California Min. Bur. Rept. 20, pp. 87-98, 1924.

25 Los Angeles field division—Santa Barbara County: California Min. Bur. Rept. 21, pp. 539-562, 1925.

25a Los Angeles field division—Ventura County: California Min. Bur. Rept. 21, pp. 223-245, 1925.

25b Los Angeles field division—Orange County: California Min. Bur. Rept. 21, pp. 58-71, illus., 1925.

25c Los Angeles field division—San Diego County: California Min. Bur. Rept. 21, pp. 325-382, illus., 1925.

26 Los Angeles field division—Imperial County: California Min. Bur. Rept. 22, pp. 248-285, illus., 1926.

27 Los Angeles field division—Los Angeles County: California Min. Bur. Rept. 23, pp. 287-354, illus., 1927.

29 Los Angeles field division—Kern County: California Div. Mines and Mining, Rept. 25, illus., 1929.

Tucker, W. Burling (Cont.)

29a (and **Sampson, R. J.**) Los Angeles field division—Riverside County: California Div. Mines Rept. 25, pp. 468-526, illus., 1929.

31 (and **Sampson, R. J.**) Los Angeles field district, San Bernardino County: California Div. Mines Rept. 27, pp. 262-401, 1931.

33 (and **Sampson, R. J.**) Los Angeles field division—Ventura County: California Div. Mines Rept. 28, pp. 247-277, 1933.

38 (and **Sampson, R. J.**) Mineral resources of Inyo County: California Div. Mines Rept. 34, pp. 368-500, 1938.

43 (and **Sampson, R. J.**) Mineral resources of San Bernardino County: California Div. Mines Rept. 39, pp. 427-549, 1943.

45 (and **Sampson, R. J.**) Mineral resources of Riverside County: California Div. Mines Rept. 41, pp. 121-182, pls. 23-35, 1945.

Turner, Henry Ward

94 The rocks of the Sierra Nevada: U. S. Geol. Survey 14th Ann. Rept., pt. 2, pp. 435-495, pls. xlviii-lix, 1894.

96 Further contributions to the geology of the Sierra Nevada: U. S. Geol. Survey 17th Ann. Rept., pt. 1, pp. 521-762, pls. 17-47, 1896.

Vaughan, Francis Edward

22 Geology of San Bernardino Mountains north of San Gorgonio Pass: Univ. California, Dept. Geol. Sci. Bull., vol. 13, pp. 319-411, 1922.

Waring, Clarence A.

19 (and **Bradley, W. W.**) Monterey County: California Min. Bur. Rept. 15, pp. 595-615, 1919.

Waring, Gerald Ashley

15 Springs of California: U. S. Geol. Survey Water-Supply Paper 338, 410 pp., maps, 1915.

Watts, W. L.

90 Solano County: California Min. Bur. Rept. 10, pp. 659-669, 1890.

90a Santa Clara County: California Min. Bur. Rept. 10, pp. 604-619, 1890.

93 Sonoma County: California Min. Bur. Rept. 11, pp. 453-464, 1893.

Wheeler, Harry Eugene

36 Stratigraphy and fauna of the McCloud limestone (abstract): Geol. Soc. America, Proc. 1935, p. 409, 1936.

Whitney, Josiah Dwight

65 Geological survey of California: geology, vol. 1; report of progress and synopsis of the field work from 1860 to 1864, xxvii, 498 pp., 1865.

Woodford, A. O.

28 (and **Harriss, T. A.**) Geology of Blackhawk Canyon, San Bernardino Mountains, California: Univ. California, Dept. Geol. Sci. Bull., vol. 17, pp. 265-304, 1928.

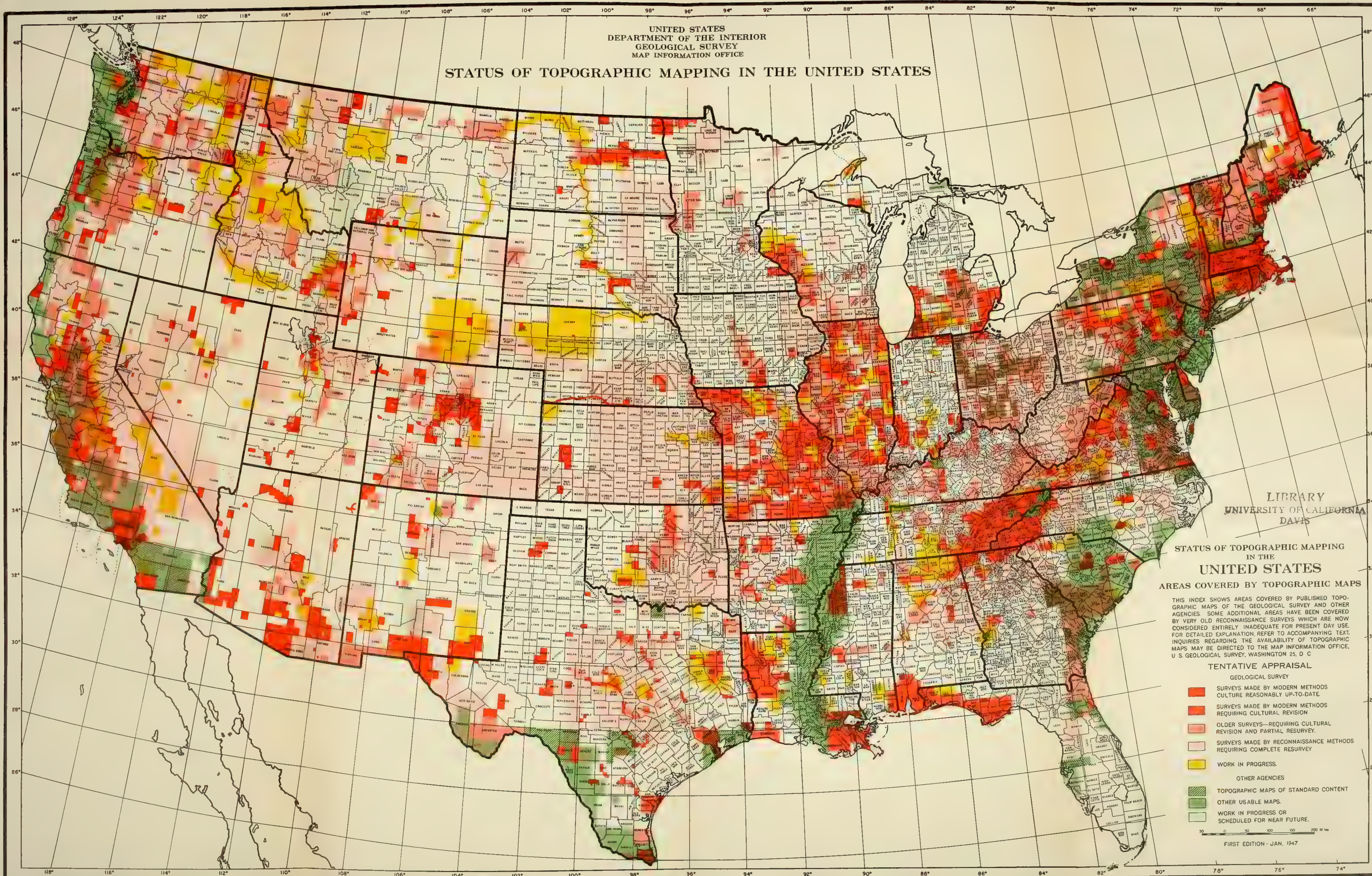
43 Crestmore minerals: California Div. Mines Rept. 39, pp. 333-365, 7 figs., 1943.

Young, George Joseph

25 Quarrying limestone by glory holes: Eng. and Min. Jour.-Press, vol. 120, pp. 13-16, 7 figs., pp. 249-253, 5 figs., 1925 . . . vol. 127, pp. 954-956, 1929.

o

74191 1-48 2M


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
MAP INFORMATION OFFICE
STATUS OF TOPOGRAPHIC MAPPING IN THE UNITED STATES
STATUS OF TOPOGRAPHIC MAPPING
IN THE
UNITED STATES
AREAS COVERED BY TOPOGRAPHIC MAPS
THIS INDEX SHOWS AREAS COVERED BY PUBLISHED TOPOGRAPHIC MAPS OF THE GEOLOGICAL SURVEY AND OTHER AGENCIES. SOME ADDITIONAL AREAS HAVE BEEN COVERED BY VERY OLD RECONNAISSANCE SURVEYS WHICH ARE NOW CONSIDERED ENTIRELY INADEQUATE FOR PRESENT DAY USE. FOR DETAILED EXPLANATION, REFER TO ACCOMPANYING TEXT. INQUIRIES REGARDING THE AVAILABILITY OF TOPOGRAPHIC MAPS MAY BE DIRECTED TO THE MAP INFORMATION OFFICE, U. S. GEOLOGICAL SURVEY, WASHINGTON 25, D. C.
TENTATIVE APPRAISAL
GEOLOGICAL SURVEY
SURVEYS MADE BY MODERN METHODS CULTURE REASONABLY UP-TO-DATE.
SURVEYS MADE BY MODERN METHODS REQUIRING CULTURAL REVISION
OLDER SURVEYS—REQUIRING CULTURAL REVISION AND PARTIAL RESURVEY.
SURVEYS MADE BY RECONNAISSANCE METHODS REQUIRING COMPLETE RESURVEY
WORK IN PROGRESS.
OTHER AGENCIES
TOPOGRAPHIC MAPS OF STANDARD CONTENT
OTHER USABLE MAPS.
WORK IN PROGRESS OR SCHEDULED FOR NEAR FUTURE.
50 0 50 100 150 200 Miles
FIRST EDITION - JAN. 1947

LIST OF LIMESTONE PROPERTIES SHOWN ON MAP

Alameda County
1 Collins deposit
2 McLaughlin lithographic stone quarry
3 Mission lime marl deposit
4 Pleasanton deposit

Alpine County
1 Grovers Hot Springs deposit

Amador County
1 Allen Estate
2 Amador lime rock deposit
3D Bakely and Garibaldi Ranches
4 Del Porto marble (Amador or Oleta marble quarry)
5 Dondero (Carrara) marble quarry
6 Elia Brothers Ranch
7 Fiddletown deposit
8 Gralich Ranch
9 Volcano limestone
10 Wait marble deposit

Butte County
1 Arlington group Arlington No 1 2 3 4 5
2 Big Bend marble quarry
3 Marysville limestone
4 McLean limestone
5 Mackey deposit
6 Parish limestone
7 Poe (King) deposit
8 Wilson limestone

Calaveras County
1 Calaveras Cement Company's plant
2 Cave City limestone deposit
3 Gale Ranch deposits
4 Markwood Ranches
5 McNamara limestone
6 Penn Plaza deposit
7 Watt and Field (Young) deposit
8 Angels marble quarry
9 Bishop marble Marble placer mine
10 Caldwell marble quarry
11 Eagle marble quarry
12 Treat marble quarry

Colusa County
1 Elgin quicksilver mine
2 Lambert Ranch
3 Manzanita mine
4 Onyx marble Aragonite California onyx

Contra Costa County
1 Henry Cowell Lime & Cement Company
2 Mt Diablo lime marl deposit

El Dorado County
1 Auburn Lime Products Co
2 Cowell Cave Valley deposit
3 Diamond Springs Lime Company
4 El Dorado Limestone Company
5 Indian Diggings marble deposit
6 Marble Valley Limestone
7 Mountain Quarries

Fresno County
1 Coral Reef Lime Products Company
2 Drake Lime Company
3 Dunlap deposits
4 Kings River deposits
5 Montford marl deposit
6 Mount Campbell Lime Company
7 San Joaquin marble deposit
8 Twin Lakes deposit
9 Webb and Mingus calcite prospect
10 Red Bud mine

Glenn County
1 Daniels deposit
2 Nye deposit

Humboldt County
1 Hackett deposit
2 Jacoby Creek deposit
3 Johnston deposit
4 McClellan deposit
5 Moore deposit
6 Richter deposit
7 Three Creeks Prospect
8 White Rock deposit

Imperial County
1 Coyote Mountains limestone
2 Creole marble deposit
3 Duseland limestone claim
4 L & S Jumbo limestone deposit
5 Mountain Springs limestone deposit
6 Southern California Development Company marble deposit
7 Waters limestone deposit

Inyo County
1 Badgley quarry
2 Blue Star Mines, Limited
3 Cartago Company
4 Cerro Gordo deposit
5D Deadfebug and Dolomite groups
6 Inyo Marble Company's deposits
7 Rogers limestone deposit

Kern County
1 Cuddy Canyon deposits
2 Erskine Creek limestone deposits
3 Jameson Lime Company
4 Monolith Portland Cement Company
5 Mountain Summit limestone deposit
6 South Fork Valley
7 Tardy limestone deposit
8 Union Lime Company

Los Angeles County
1 Algal limestone
2 Palos Verdes deposit
3D Boughman dolomite deposit
4D Haskins dolomite deposit
5D Ramelli deposit
6 San Fernando deposit

Madera County
1 Chowchilla marble deposit
2 B & W Tungsten Company claims
3 Scott marble deposit

Marin County
1 Olema deposit
2 Tomales Bay deposit

Mariposa County
1 Bower Cave deposits
2 Cotton Creek deposit
3 Emory quarry
4 Marble Point deposit
5 O'Brien limestone deposit
6 Walsh and Forney deposit

Mendocino County
1 Fisher Ranch deposit
2 Quinan Ranch deposit

Mono County
1 Bridgeport travertine deposits
2 Spar group and Spar King

Monterey County
1 Chalone Creek deposit
2 Gabilan Peak (Bardin) deposit
3 Henry Cowell Lime & Cement Company
4 Los Vergeles Ranch deposits
5 Marble Peak deposit
6 Monterey Lime Company
7 Nelson Creek deposits
8 Patriquin marble deposit
9 Unnamed deposits in Jamesburg quadrangle sec. 34 T 17 S R 3 E
10 Unnamed deposits in Jamesburg quadrangle secs. 17 18 20, T 18 S R 4 E
11 Unnamed deposits in Jamesburg quadrangle secs. 17 20 T 19 S R 3 E (3 separate small deposits)
12 Pico Blanco deposit
13D Permanente Metals Corporation
14D Pacific Coast Steel Company

Nevada County
1 Bear River marble
2 Greenhorn River lime kiln
3 Lime Kiln Ranch
4 South Fork Yuba River

Orange County
1 Capistrano deposit
2 El Toro deposit
3 Ladd Canyon deposit

Placer County
1 Bear River marble (formerly Holmes Lime & Cement Company)
2 Burton (Patterson) deposit
3 Cowell deposit
4 Oe Wim limestone
5 Hotaling deposit
6 Jumbo No. 1 lode & mill site
7 Lime Rock deposit
8 Lime Rock deposit (another deposit under same ownership)
9 Matthews deposit
10 Muegge deposit
11 Pacific Portland Cement Company
12 Spreckels limestone deposit
13 Sullivan and McCormick claim

Plumas County
1 Limestone Point deposit
2 Marble Cone
3 Pyramidal lime deposit
4 Silver White placer claim
5 Western Star travertine deposit

Riverside County
1 Blythe Cement claims nos. 1 to 5
2 Carbonate Blanket group
3 Eden Hot Springs deposit
4 Gulberson limestone deposit
5 Harris limestone deposit
6 Hubbard limestone deposit
7 Lamb Canyon deposit
8 Magstone Products
9 Mammoth 7 limestone claim
10 Moore limestone deposit
11 Novell limestone deposit
12 Pinyon Flat
13 Riverside Cement Company
14 San Jacinto Rock Products Company
15 Southern Pacific Land Company
16 Whitecap limestone no. 1 and no. 2 claims

San Benito County
1 Archer Lime Company
2, 2D Crowe Ranch deposits
3 George Melendey Ranch
4 Hamilton (Scott Ranch) deposit
5 Harlan limestone deposit
6 Henry Cowell Lime & Cement Company
7 McPhail deposits
8 Old Mission Portland Cement Company
9 San Benito Lime Company
10D Permanente deposit
11D A. E. Hamilton
12D Martin Ranch deposit
13D O'Hara Ranch deposit

San Bernardino County
1 Adelanto deposit
2 Arlington and Black Hawk groups
3 Baker limestone deposit
4 Baxter and Ballardie limestone deposits
5 Big Pine deposit
6 Cajon limestone deposit
7 California Portland Cement Company
8D Chalmers dolomite deposit
9 Chubbuck Lime Company deposits
10 & 10D Chubbuck reserve limestone and dolomite deposits
11 Cima limestone deposit
12 Devil's Canyon limestone deposit
13 Dunton limestone deposit
14D Hesperia dolomite deposit
15D Hinkley dolomite deposit
16 Jack Frost deposit
17D Johnson dolomite deposit
18 Lamb Brothers limestone deposits
19 Lawton deposit
20 Marble placer claim
21D Magnesium Giant mine
22 McAntire and Proctor marble deposit
23 Mill Creek Limestone Company deposit
24 Mojave marl deposit
23 & 25D O'Connell limestone and dolomite deposit
26 Peterson limestone deposit
27D Richter dolomite deposit
28 Riverside Portland Cement Company Oro Grande quarry and plant
29 Silver Dome deposit
30 Silver Lake deposit
31 Snowcap deposit
32 Southwest Portland Cement Company California plant
33 Standard limestone deposit
34D Sugar Loaf Mountain dolomite deposit
35 Victorville Lime Rock Company
36 Verde Antique marble
37 Vaughan marble
38 Twin Buttes dolomite
39 Alamo marble

San Diego County
1 Borrego Springs deposit
2 Brockman marble deposit
3 Deer Park limestone deposit
4 Dos Cabezas limestone deposits
5D Elliott dolomite property
6 Golden State marble deposits
7 Heathman quarry
8 Lakeside lime and marl deposit
9 Verruga marble quarries

San Luis Obispo County
1 Dubost limestone deposit
2 Lime Mountain deposit
3 Lopez Canyon group
4 Tassajara group
5 Almaden deposit
6 Lowe, Porter, et al
7 Morgan deposit
8 Newsom marl deposit

San Mateo County
1 Pacific Portland Cement Company
2 Rockaway Quarry, Inc
3 Ken Royce Construction Equipment Company
4 W. O. Tyson

Santa Barbara County
1 Lind deposit
2 Sierra Blanca limestone

Santa Clara County
1 Bay Shell Company
2 Beck Dredging Company
3 Bernal marl and limestone deposit
4 Bond limestone deposit
5 Douglas Ranch or Ellis limestone deposit
6 San Jose Cement Company
7 Black Mountain limestone deposits

Santa Cruz County
1 Henry Cowell Lime & Cement Company
2 Holmes Lime Company
3 Pacific Limestone Products Company
4 Santa Cruz Portland Cement Company plant

Shasta County
1 Alta Lime & Brick Company
2 Asher limestone
3 Bear Mountain
4 Bibbens limestone
5 Brock Mountain deposit
6 Briggsville (Moorestown) limestone
7 Doak deposit
8 Emerald Glen Ranch
9 Gray Rocks deposit
10 Hart and Gregg deposit
11 Morley deposit
12 Shasta Iron Company deposit

Sierra County
1 Unnamed deposits

Siskiyou County
1 Hathaway limestone quarry
2 Mt. Shasta Lime Company
3 Sec. 24, T 40 N, R 9 W, M.D. (old lime kiln)
4 Sec. 17 T 43 N, R 9 W, M.D. (old lime kiln)
5 Sec. 18 T 46 N, R 9 W, M.D. (marble)
6 Sec. 6, T 41 N, R 9 W, M.D. (marble)
7 Sec. 32 T 42 N, R 9 W, M.D. (marble)
8 Sec. 8 T 17 N, R 8 E, H. (marble)
9 Secs. 13 24 T 47 N, R 8 W, M.D.
10 West ½ T 41 N, R 8 W, M.D.
11 Secs. 27 34, T 42 N, R 8 W, M.D.
12 Secs. 35 36, T 43 N, R 8 W, M.D.
13 Secs. 1 12 13 14, T 42 N, R 7 W, M.D.
14 NW¼ T 42 N, R 7 W, M.D.
15 Marble Mountain region in T 43 44 N, R 12 W

Sonoma County
1 Black Ranch deposit
2 Healdsburg Marble Company
3 Purviance Ranch

Trinity County
1 Sec. 21 T 33 N, R 9 W, M.D.
2 Sec. 3, T 33 N, R 10 W, M.D.

Tulare County
1 Blossom Peak limestone Noel Britten, N½ Daniel Allen SE¼SE¼ Byron Allen all of SE¼ except SE¼SE¼
2 Cortner group
3 Devil's Thumb claims
4 Gill Ranches
5 Holdridge deposit
6 Lovelle deposit
7 Lemon Cove deposit
8 Moorehouse Creek limestone deposits
9 Simons limestone deposit
10 Parts of secs. 24 25, T 22 S, R 32 E
11 Parts of secs. 19 30, T 22 S, R 33 E
12 Parts of secs. 1 11 12 13, T 23 S, R 32 E
13 Parts of secs. 6 7 18, T 23 S, R 33 E

Tuolumne County
1 Bell Columbia marble quarry
2 G. Bardoli & Bros. quarry
3 Childress Ranch
4 Columbia marble quarry
5 Dunning Ranch
6 Engler Lime Company

EXPLANATION
Location of properties, numbered by counties. "D" indicates dolomite

SCALE
0 10 20 30 40 50 60 70 80 90 100 MILES

MAP OF CALIFORNIA
SHOWING
DISTRIBUTION OF LIMESTONE PROPERTIES

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO
OLAF P. JENKINS, Chief

Vol. 43 | OCTOBER 1947 | No. 4

CALIFORNIA JOURNAL

OF

MINES AND GEOLOGY

STATE OF CALIFORNIA

EARL WARREN, Governor

DEPARTMENT OF NATURAL RESOURCES

WARREN T. HANNUM, Director

DIVISION OF MINES

OLAF P. JENKINS, Chief

Headquarters

Third Floor, Ferry Building, San Francisco 11

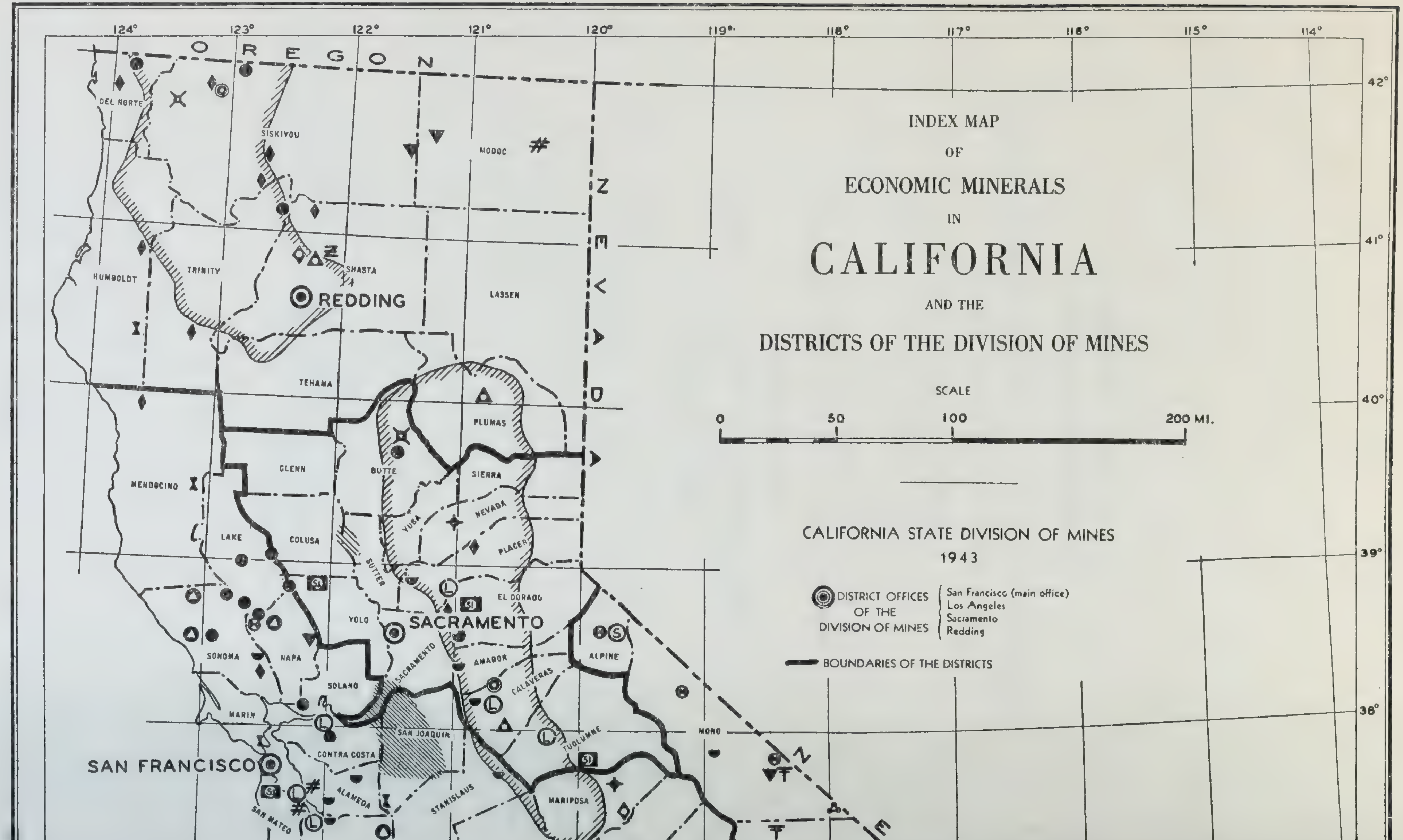
District Offices

State Building, 217 West First Street, Los Angeles 12
631 J Street, Sacramento 14
Box 445, Redding

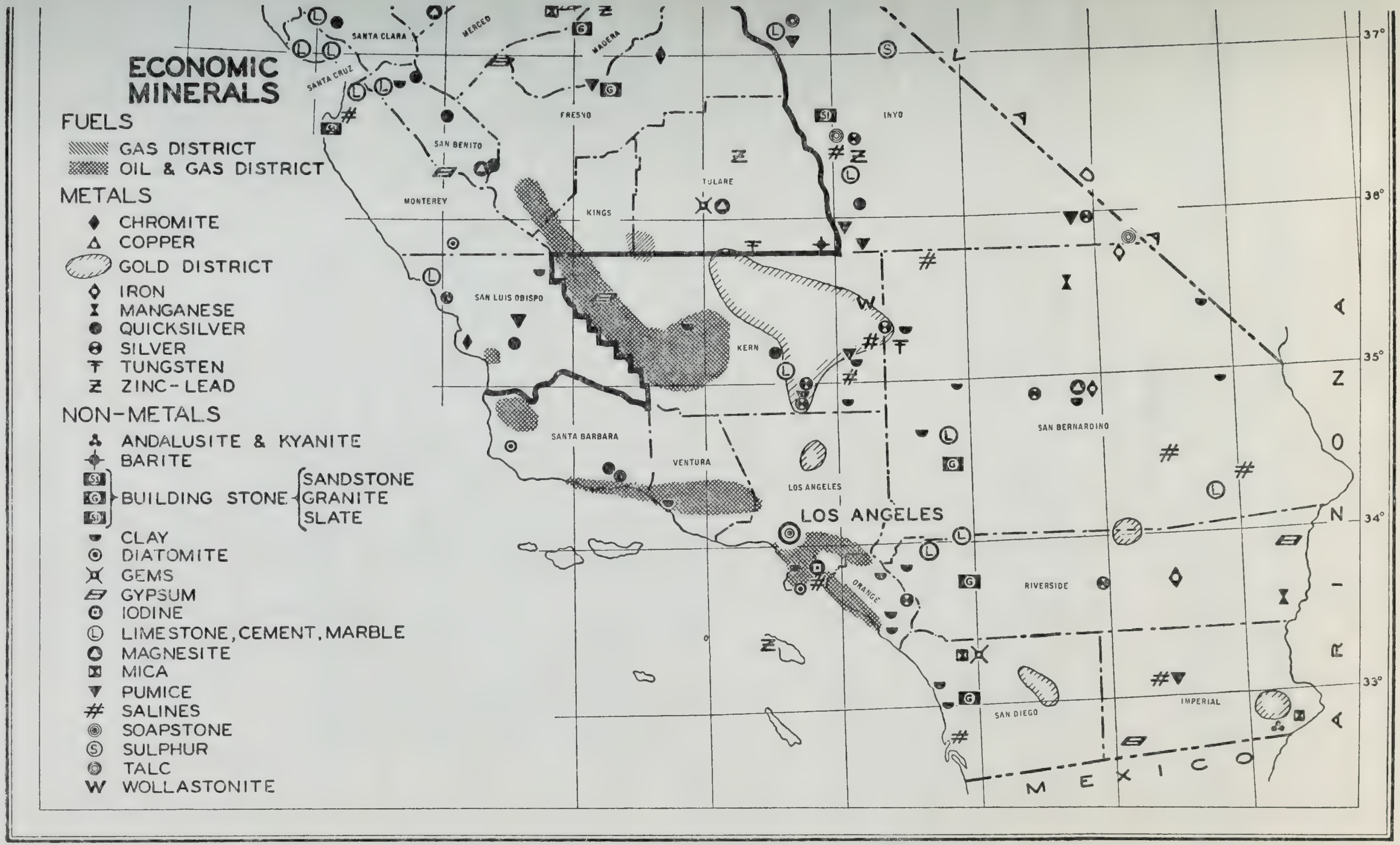
The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles and Sacramento district offices.

In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology and mining of California, is given to the public by means of publications, mimeograph releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines consist of the quarterly periodical **California Journal of Mines and Geology**, issued in January, April, July, and October of each year, and a series of **Bulletins.** Mimeographed **Information Circulars** and **Announcements of New Publications** are also released periodically. A list of publications will be sent free upon request.



INDEX MAP
OF
ECONOMIC MINERALS
IN
CALIFORNIA
AND THE
DISTRICTS OF THE DIVISION OF MINES
SCALE
0
50
100
200 MI.
CALIFORNIA STATE DIVISION OF MINES
1943
DISTRICT OFFICES OF THE DIVISION OF MINES
San Francisco (main office)
Los Angeles
Sacramento
Redding
BOUNDARIES OF THE DISTRICTS
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°
OREGON
NEVADA
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
MENDOCINO
YUBA
NEVADA
LAKE
COLUSA
PLACER
SUTTER
EL DORADO
YOLO
SACRAMENTO
ALPINE
SONOMA
NAPA
AMADOR
SOLANO
SACRAMENTO
CALAVERAS
MARIN
SAN JOAQUIN
TUOLUMNE
MONO
SAN FRANCISCO
CONTRA COSTA
ALAMEDA
SAN MATEO
STANISLAUS
MARIPOSA


ECONOMIC MINERALS
FUELS
GAS DISTRICT
OIL & GAS DISTRICT
METALS
CHROMITE
COPPER
GOLD DISTRICT
IRON
MANGANESE
QUICKSILVER
SILVER
TUNGSTEN
ZINC-LEAD
NON-METALS
ANDALUSITE & KYANITE
BARITE
BUILDING STONE
SANDSTONE
GRANITE
SLATE
CLAY
DIATOMITE
GEMS
GYPSUM
IODINE
LIMESTONE, CEMENT, MARBLE
MAGNESITE
MICA
PUMICE
SALINES
SOAPSTONE
SULPHUR
TALC
WOLLASTONITE
SANTA CLARA
SANTA CRUZ
MERCED
MADERA
SAN BENITO
FRESNO
INYO
MONTEREY
KINGS
TULARE
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
LOS ANGELES
SAN BERNARDINO
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
NEVADA
ARIZONA
MEXICO
37°
36°
35°
34°
33°

CONTENTS

PLATES

ANNUAL REPORT, DIVISION OF MINES FOR THE NINETY-EIGHTH FISCAL YEAR, JULY 1, 1946, TO JUNE 30, 1947

(Part 1 of Biennial Report required by Section 2203, Public Resources Code)

By Olaf P. Jenkins *

OUTLINE OF REPORT

ILLUSTRATIONS

* Chief, California State Division of Mines. Manuscript submitted for publication December 1947.

LETTER OF TRANSMITTAL

General Warren T. Hannum
Director, Department of Natural Resources
Sacramento, California

SIR:

I have the honor to transmit herewith for reference to Governor Earl Warren the annual report of the Division of Mines for the 98th fiscal year, July 1, 1946, to June 30, 1947.

Section 2203 of the Public Resources Code provides:

"The State Mineralogist shall make a biennial report to the Governor on or before the fifteenth day of September next preceding the regular session of the Legislature."

Since the state budget is now submitted annually to the Legislature for fiscal year appropriation of funds for the support of the state's administration, the Director of the Department has with the concurrence of the State Mining Board, directed that an annual fiscal year report be submitted.

The last biennial report of the State Mineralogist was prepared by Walter W. Bradley, retired as of August 31, 1946. Mr. Bradley served 2 months of the 98th fiscal year. The present incumbent took office February 1, 1947. During the intervening five months W. Burling Tucker, who was District Mining Engineer of Los Angeles, served under temporary appointment.

In assuming the responsibilities of administering the affairs of the Division of Mines on a permanent basis, under supervision of the Director and in consultation with the Mining Board, the Division has been reorganized along functional lines and its activities realigned to meet its statutory duties more fully.

In arranging for specific assignments, emphasis is being placed, wherever possible, to meet the current public demand and the many special requests made by public-spirited committees throughout the state.

Examples of such special requests are as follows: Chambers of Commerce of Alameda, Madera, Fresno, Tulare, Sonoma, and San Diego Counties have recently requested up-to-date reports and maps of the mineral resources of their counties. San Diego County asks also for a special study of local monumental stone. The aggregates industries desire studies made of important local sources of supplies. The ceramic society desires a statewide survey of clays. The cement industry wants careful surveys made of limestone deposits of the state. A survey of the coal resources of California is requested by the State Chamber of Commerce. The Shasta-Cascade area of six counties recently requested that studies be made of its mineral deposits, mineral markets, and methods of mineral beneficiation; it also desires further basic geologic mapping, the preparation of a geologic guidebook along the Klamath River, and publication of reports prepared in non-technical language for aid in prospecting and mineral development.

The extent to which the Division may go in fulfilling these timely and urgent requests is limited by appropriations, which have been designed largely to care for the regular routine work of the Division in inventorying mining operations and production, in providing information to the public, and in carrying on basic statewide and fundamental studies of mineral resources.

To meet the ever-increasing demands of the public and of the expanding mineral industry, the Division of Mines must provide for more extensive, well-integrated surveys of the state's richly endowed mineral commodities, a service which should bring dividends to California in this period of expansion in population and markets.

Respectfully submitted,

OLAF P. JENKINS
Chief, Division of Mines
(State Mineralogist)
September 15, 1947.

STATUTORY FUNCTIONS

The Public Resources Code summarizes the functions of the Division of Mines as follows:

"2205. The State Mineralogist shall:

"(a) Make, facilitate, and encourage special studies of the mineral resources and mineral industries of the State.

"(b) Collect statistics concerning the occurrence and production of the economically important minerals and the methods pursued in making their valuable constituents available for commercial use.

"(c) Make a collection of typical geological and mineralogical specimens, especially those of economic and commercial importance such collection constituting the museum of the division.

"(d) Provide a library of books, reports, and drawings bearing upon the mineral industries, the sciences of mineralogy and geology, and the arts of mining and metallurgy, such library constituting the library of the division.

"(e) Make a collection of models, drawings, and descriptions of the mechanical appliances used in mining and metallurgical processes.

"(f) Preserve and so maintain such collections and library as to make them available for reference and examination, and open to public inspection at reasonable hours.

"(g) Maintain, in effect, a bureau of information concerning the mineral industry of this State to consist of such collections and library, and arrange, classify, catalogue, and index the data therein contained, in a manner to make the information available to those desiring it.

"(h) Issue from time to time such bulletins as he may deem advisable concerning the statistics and technology of the mineral industries of this State."

The words "mine" and "mineral" are defined as follows:

"2200. For the purposes of this chapter 'mine' includes all mineral bearing properties of whatever kind or character, whether underground, quarry, pit, well, spring or other source from which any mineral substance is or may be obtained. 'Mineral' for the purposes of this chapter includes all mineral products both metallic and nonmetallic, solid, liquid or gaseous, and mineral waters of whatever kind or character."

It is stated that:

"507. The Division of Mines shall be administered through a chief who shall be known as the State Mineralogist. He shall be a technically trained mining engineer, appointed by the director upon nomination by the State Mining Board. General policies for the guidance of the Division of Mines shall be determined by a State Mining Board, which shall consist of five members appointed by and holding office at the pleasure of the Governor."

Since the term "mineralogist" is ordinarily limited to one who specializes in the science of mineralogy and crystallography, rather than in mineral economics, mining engineering, geological exploration, and other requirements of the position, the term Chief, Division of Mines has been adopted by the Department for administrative usage.

Provisions for the securing of personnel to carry on the work required is as follows:

"2201. The State Mineralogist shall employ competent geologists, field assistants, qualified specialists, and office employees when necessary in the execution of the plans and operations of the division under this chapter. . ."

In order to fulfill these and other requirements of the Public Resources Code, it has been necessary to reorganize the Division of Mines on a functional basis.

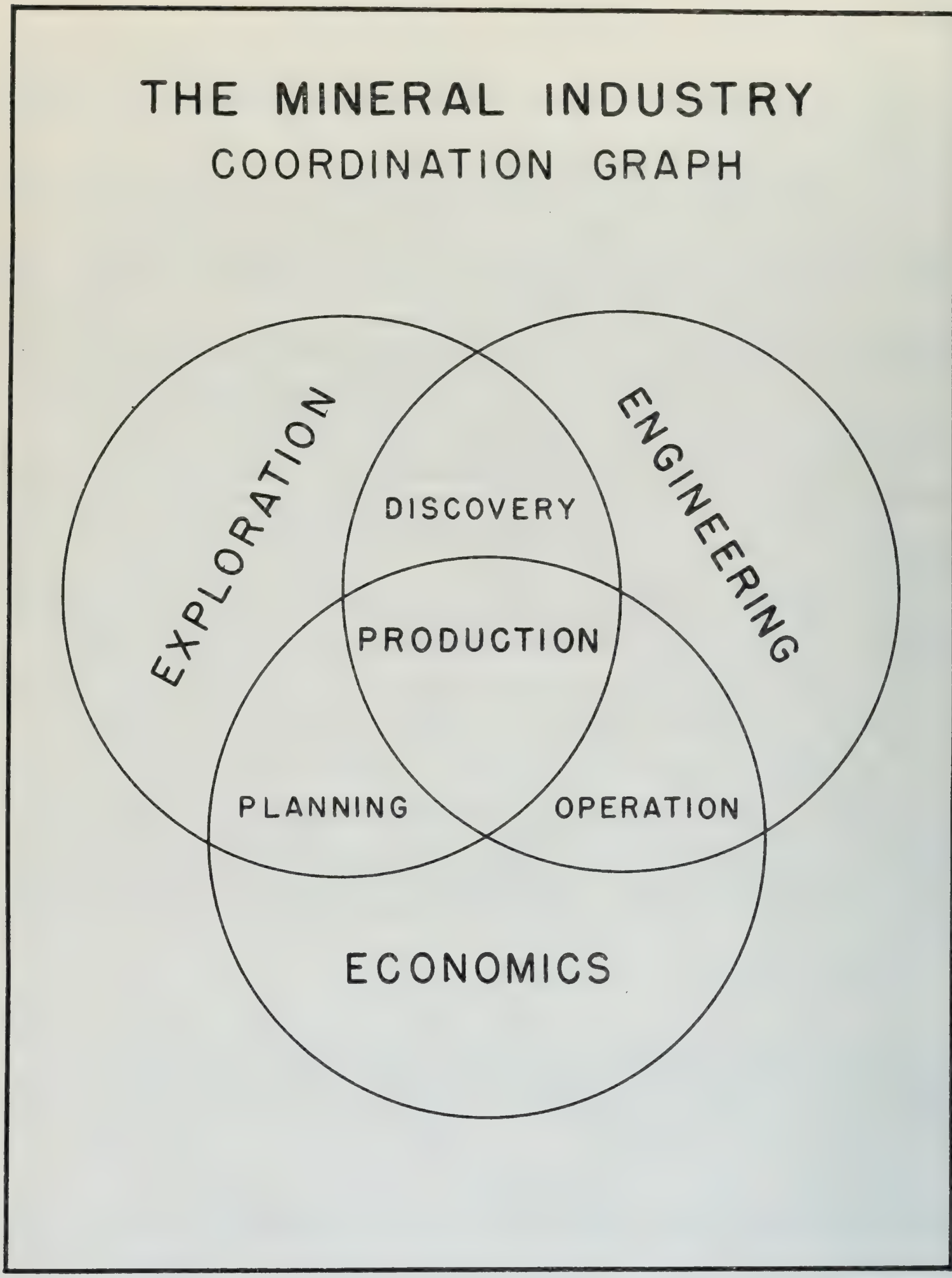


FIGURE 1. Diagram to show the three principal subjects of study in the development of the mineral industry, and how these subjects are interrelated. The study of economics and engineering requires the state to keep inventories of production and operation; exploration gives opportunity for geologic research and discovery of the occurrence, nature, and reserves of minerals, both of immediate and potential commercial value.

FUNCTIONAL REORGANIZATION

New Order

A department which has been in existence for nearly three-quarters of a century has necessarily built up a pattern of work which has adjusted itself along certain grooves of routine, originally intended to meet the earlier needs of the mining industry of the state. Many of these needs still exist, but during the past several years the mineral requirements of the state and the nation have been enormously increased and have in large part changed to a different order. For this reason it has been necessary during the past year to begin the alteration and reorganization of the Division of Mines to conform with modern development of science, engineering, and mineral economics.

In reviewing the functional scope of this organization, and in studying the requirements laid down by the Public Resources Code, it is found that the Division of Mines is actually a division of mineral resources, not merely required to study mining properties in operation, but to survey the entire extent of the state's mineral resources and the reserves of mineral commodities required by modern industry, which constantly changes its specifications for raw products.

Fundamental Activities

The fundamental activities of a state bureau such as the Division of Mines fall naturally into three distinct but coordinated activities: The first is fundamental field exploration, the function of geology; the second is mineral economics, which places before us the value, utilization, and distribution of mineral resources, as well as past and possible future production; the third is the engineering procedure necessary to extract minerals and rocks, and to process them so that they may be in a form most useful to industry. The view in these three fundamental studies should be forward-looking, not merely dwelling in the past, but reaching out to show the way to a more useful and better world of tomorrow.

The whole plan of the work of the Division of Mines must, therefore, be governed by the three fundamental activities, evenly balanced—exploration, economics, engineering—which have built up the entire industrial development and utilization of metals, minerals, and rocks.

Scope of Activities

In examining the scope of the mineral resources available in the State of California it is found that the state is endowed abundantly, both in quantity and quality of raw products. In classifying these mineral resources into three categories—mineral fuels, non-metals, and metals—it is found that the value of their production at the present day is of the following relative importance: Mineral fuels 80 percent, non-metals 16½ percent, metals 3½ percent. The total annual production exceeds half a billion dollars. The State of California spends one-twentieth of 1 percent of this sum for the work of the State Division of Mines, which is intended to assist the entire mineral industry in its function to contribute to the development of an efficient and coordinated modern civilization.

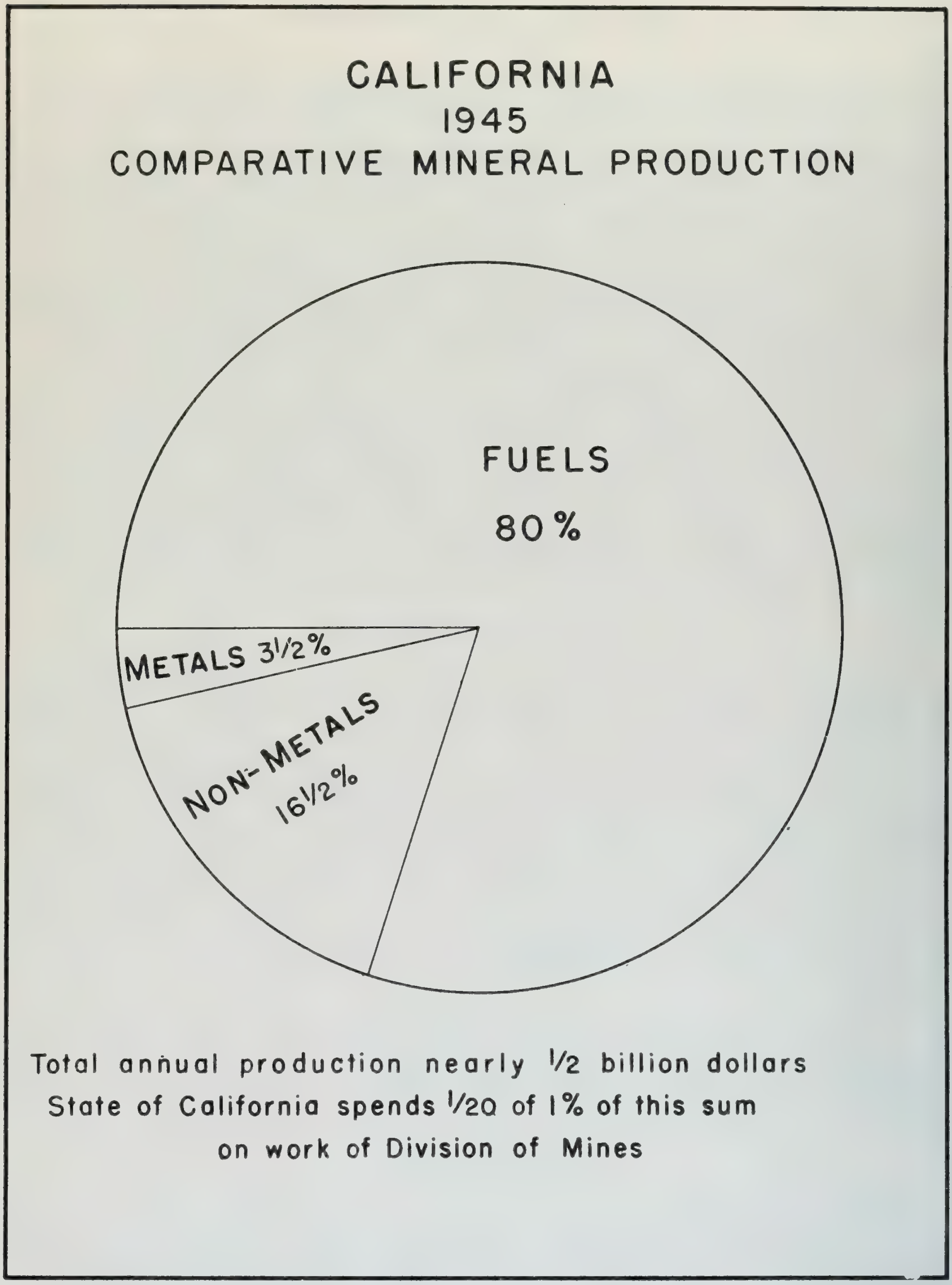


FIGURE 2. Diagram to show the relative importance of mineral fuels, non-metallics, and metals, from the standpoint of value of production in California during the year 1945. The state may render outstanding services to all of these groups of industries: (a) by basic geologic mapping for all three; (b) by commodity and market studies for the non-metals group; (c) by treatment and beneficiation studies for metals; and (d) by operational studies for both metals and non-metals.

The inter-relationship of the manifold existing mineral industries of the nation is exceedingly complex. Certain types of raw mineral products form the basis of our greatest industries. Without all or any of these basic minerals (such as mineral fuels, iron, limestone, soda ash, salt, sulphur, mineral fillers, ceramic clays) great industries are forced to develop elsewhere than in our state. It should be the function of the Division of Mines, therefore, to endeavor to find and assist in the development of these and all other necessary basic products within our own state; but failing, we should welcome the importation from another state of any product in which we are deficient. In so doing we may utilize deposits of many minor minerals and rocks, otherwise neglected, in the new industries, and we may exchange our products with those of other states. The latent mineral resources of California probably form its greatest potential wealth, now awaiting future civilization to develop.

Taking this broader point of view, that the Division of Mines should look to the future and survey its entire mineral and rock resources, we must plan and reorganize on a broader, more modern basis. The attached chart demonstrates how the Division of Mines is now organized along functional lines of activity, which are closely coordinated with each other as shown in the accompanying outline.

OUTLINE OF THE FUNCTIONAL ORGANIZATION AND CHANNELS OF PRINCIPAL ACTIVITIES OF THE DIVISION OF MINES

A. Administration
   1. Integration of various lines of activities
      Example: By coordination of commodity study, resources (geology) with mineral economics (engineering)
   2. Execution of policies made by Mining Board
   3. Personnel work
   4. Finance and budgets
   5. Publications
   6. Assignment of mail (inquiries) to specialists on staff for answering
   7. Public relations
      a. Distribution of publications and information services
      b. Public appearances and addresses
      c. Direct assistance by contact with individuals in the field and office
      d. Indirect assistance by supplying consultants with technical information for their use in advising individuals
      e. Regional coordination of data, such as statewide maps, statewide reports, etc.
   8. Reports to the Director on summary of activities and operations

B. Mining Engineering Branch
   1. Minerals Economics Section
      a. Uses, prices, markets, specifications, treatment, tariffs, taxes, control, and legislation of minerals
      b. Mineral statistics.
   2. Investigations of development and operations; function of the district offices
      a. Mining methods
      b. Mineral-dressing methods
      c. New operations and plants
      d. County reports

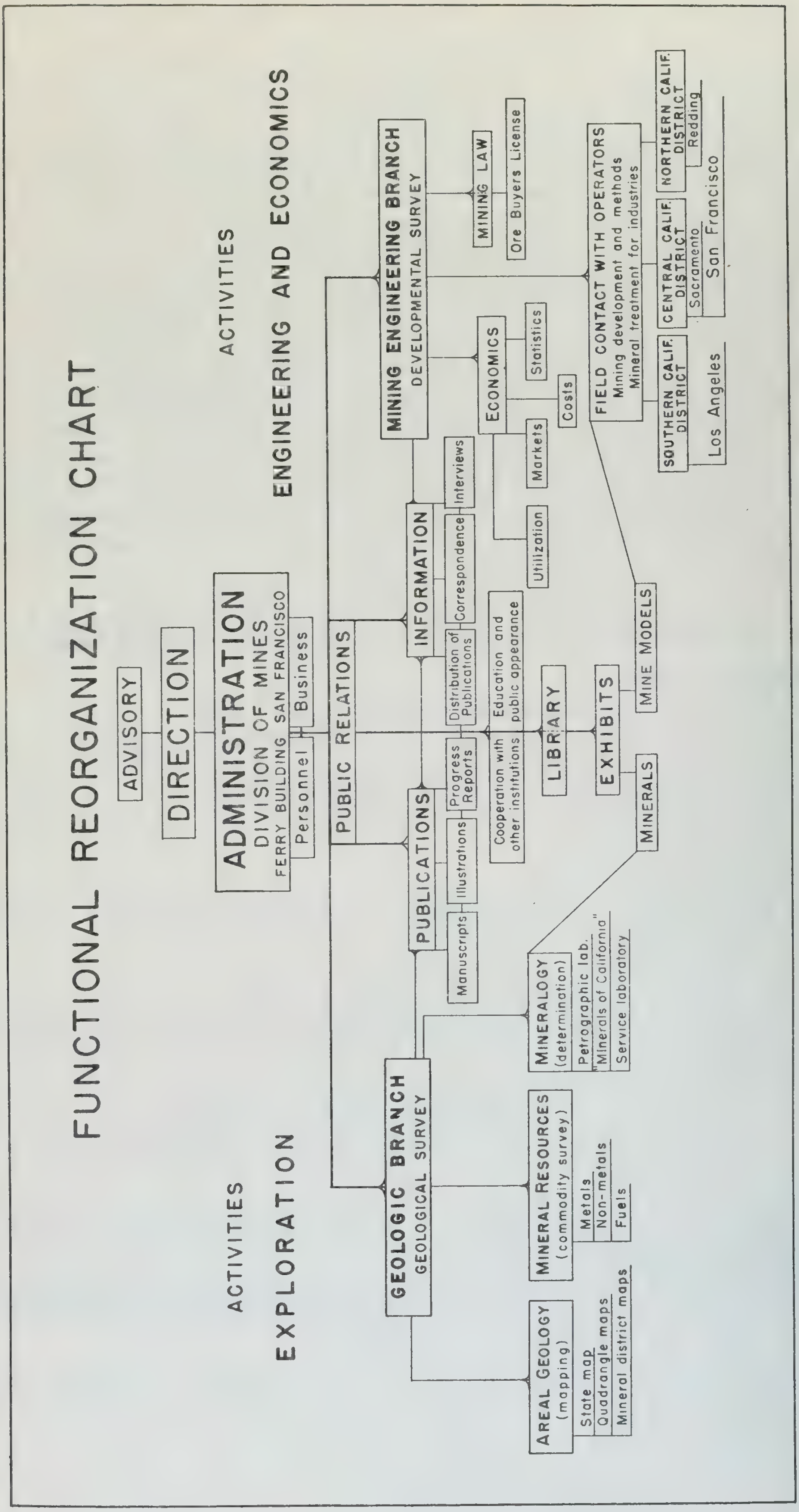

FUNCTIONAL REORGANIZATION CHART
ADVISORY
DIRECTION
ADMINISTRATION
DIVISION OF MINES
FERRY BUILDING SAN FRANCISCO
Personnel
Business
PUBLIC RELATIONS
ACTIVITIES
EXPLORATION
ACTIVITIES
ENGINEERING AND ECONOMICS
GEOLOGIC BRANCH
GEOLOGICAL SURVEY
MINING ENGINEERING BRANCH
DEVELOPMENTAL SURVEY
PUBLICATIONS
Manuscripts
Illustrations
Progress Reports
Distribution of Publications
INFORMATION
Correspondence
Interviews
Cooperation with other institutions
Education and public appearance
LIBRARY
EXHIBITS
MINERALS
MINE MODELS
AREAL GEOLOGY (mapping)
State map
Quadrangle maps
Mineral district maps
MINERAL RESOURCES (commodity survey)
Metals
Non-metals
Fuels
MINERALOGY (determination)
Petrographic lab.
"Minerals of California"
Service laboratory
ECONOMICS
Markets
Costs
Statistics
Utilization
MINING LAW
Ore Buyers License
FIELD CONTACT WITH OPERATORS
Mining development and methods
Mineral treatment for industries
SOUTHERN CALIF. DISTRICT
Los Angeles
CENTRAL CALIF. DISTRICT
Sacramento
San Francisco
NORTHERN CALIF. DISTRICT
Redding

FIGURE 3.

3. Information service, supplied from headquarters and district offices
4. Ore-buyers licenses
5. Mining law and new legislation

C. Geologic Branch
1. Geological survey; largely through cooperation with U. S. Geological Survey and universities
    a. State map, small scale, regional mapping (compilation)
    b. Large-scale maps: quadrangle mapping, scale 1:62,500 and 1:24,000
    c. Mapping mineral belts
2. Commodity survey (resources, occurrence, distribution, extent, grade, composition, structure, and other geologic studies including large-scale local geologic mapping)
    a. Metals
    Statewide reports on manganese, chrome, iron, copper, quicksilver, lead and zinc, gold and silver, tungsten, etc.
    b. Nonmetals
    Statewide reports on limestone and dolomite, clay, salines, sand, aggregates, pumice, talc, magnesite, gypsum, feldspar, gem minerals, pyrophyllite, perlite, etc.
    c. Fuels
    Oil and gas; coal and lignite
    Example: Bulletin 118.
3. Mineralogy and petrography
    a. Laboratory service to the public (continuous)
    b. Mineral exhibits for public (museum)
    c. Compilation and research of statewide occurrences, minerals, not necessarily commercial
    Example: "Minerals of California," in press (cooperation with U. C. L. A.)
    d. Determination of minerals and rocks for staff members (not general public service)
    e. General assistance to commodity survey
4. Drafting
    a. Preparation of maps, charts, etc. for publication; coordinated with editorial section; service to entire Division of Mines
    b. Maintenance of map room and map references, and indexes; coordinated with library

D. Editorial section
1. Editing of all publications of Division of Mines, both printed and mimeographed material
2. Special bibliographies to accompany publications, or to be published separately
3. Control of mailing lists
4. Preparation of reports of progress and announcements of publications

E. Library
1. Accession of books by purchase, exchange, and gifts
2. Active cooperation with other libraries; extension of informational service of Division of Mines

3. References, bibliographies, and information on sources of data; service to the public and to the staff
4. Cataloging and care of library and reading rooms

F. Office service
1. Stenographic clerical pool, including mimeograph and addressograph work, ordering, and local accounting
2. Stockroom, including mailing and property inventory
3. Janitor, including guard duty part of the time

FINANCIAL STATEMENT

Expenditures

A summary of the expenditures of the Division of Mines during the 98th fiscal year is shown in the following financial statement.

Table 1. Department of Natural Resources, Division of Mines statement of expenditures, July 1, 1946 to September 30, 1947

Function	Salaries and wages	Operating expenses	Equipment	Total
Executive	$8,000.24	$1,924.73	$10.42	$9,935.39
Field	55,431.97	4,810.77	1,970.99	62,213.73
Geology	14,629.09	1,327.13	258.67	16,214.89
Laboratory	5,501.41	540.73	3.60	6,045.74
Library	4,404.13	715.73	1,789.43	6,909.29
Mining Board		982.18		982.18
Office	12,986.19	10,299.17	1,204.22	24,489.58
Ore buyers inspection	7,175.98	1,166.08	26.14	8,368.20
Publications		3,492.39	673.94	4,166.33
Statistics and museum	1,934.56	191.19	147.96	2,273.71
Total	110,063.57	25,450.10	6,085.37	141,599.04
Special item: Geological exploration in cooperation with U. S. Geological Survey				28,907.57
Grand total				170,506.61

Comparative Support

In comparing state support of the mineral industry to that of the agricultural industry, we find that the latter has the advantage five or six-fold, as indicated by the following table.

Table 2. Comparative state support of the mineral and agricultural industries

Industry	Total income of industry	State support	Support per $1,000 produced
1945			
Agriculture	$1,826,155,000	$4,280,510	$2.34
Mines	473,662,000	161,113	0.34
1946			
Agriculture	1,974,275,000	5,747,227	2.91
Mines	516,685,000	259,200	0.50

Comparison With Other States

California compares favorably with most other states in its support of the mineral industry; but in several cases it lags far behind, as shown in table 3.

Table 3. Comparison of mineral output and appropriations in the various states

State	Value of 1945 mineral output*	State's appropriation for geological and mining departments **	Dollars appropriated per $1,000 produced	Principal mineral products for 1944 in order of their value
Texas	$1,360,694,000	$64,450	$0.05	Petroleum, natural gas, natural-gas gasoline, sulphur, liquefied petroleum gases, cement, miscellaneous stone, clay products, salt, magnesium compounds, clay crude
Pennsylvania	930,133,000	112,500	0.12	Coal, petroleum, natural gas, miscellaneous stone, cement, clay products, lime, clay raw, slate
California	627,306,000	193,791	0.31	Petroleum, natural gas, natural-gas gasoline, cement, miscellaneous stone, borates, potash, clay products, liquefied petroleum gases, gold, soda, salt, magnesium compounds, quicksilver, tungsten ore, zinc, diatomite, clay, copper, lead, lime
West Virginia	597,377,000	50,000	0.08	Coal, natural gas, petroleum, cement, miscellaneous stone, lime, natural-gas gasoline, clay products, clay
Illinois	332,489,000	384,464	1.16	Coal, petroleum, miscellaneous stone, cement, clay products, fluorspar, liquefied petroleum gases, natural-gas gasoline, natural gas, lime, zinc, clay
Louisiana	298,842,000	43,000	0.14	Petroleum, natural gas, natural-gas gasoline, sulphur, salt, liquefied petroleum gases, miscellaneous stone
Oklahoma	282,859,000	57,450	0.20	Petroleum, natural gas, zinc, natural-gas gasoline, coal, liquefied petroleum gases, lead, miscellaneous stone
Kansas	210,187,000	92,400	0.44	Petroleum, natural gas, zinc, coal, cement, miscellaneous stone, salt, natural-gas gasoline, clay products, lead
Ohio	196,633,000	31,300	0.16	Coal, natural gas, clay products, miscellaneous stone, lime, cement, petroleum, clay, salt
Minnesota	167,140,000	7,760	0.05	Iron ore, manganiferous iron ore, miscellaneous stone, cement
Michigan	140,677,000	198,025	1.43	Iron ore, petroleum, natural gas, miscellaneous stone, salt, cement, copper, magnesium compounds, clay products
Utah	129,386,000	none	0.00	Copper, coal, gold, zinc, lead, silver, iron ore, sand, gravel and stone, cement, asphalt, natural gas
New Mexico	116,508,000	50,000	0.43	Petroleum, potash salts, copper, natural gas, zinc, coal, natural-gas gasoline, lead
Alabama	111,158,000	59,455	0.53	Coal, iron ore, cement, stone, miscellaneous stone, lime, clay products, bauxite
Arizona	98,533,000	25,390	0.26	Copper, zinc, lead, gold, silver
Montana	75,816,000	25,000	0.33	Copper, petroleum, coal, natural gas, manganese ore, silver, zinc, lead, gold, cement, miscellaneous stone
Idaho	44,387,000	17,500	0.39	Zinc, lead, silver, cement
Washington	31,588,000	Not available	------------	Coal, miscellaneous stone, cement, zinc, gold, copper, clay products
Nevada	31,517,000	10,000	0.32	Copper, zinc, gold, tungsten ore, lead, miscellaneous stone
Oregon	9,398,000	70,410	7.49	Cement, miscellaneous stone

* Value of 1945 mineral output taken from the U. S. Bureau of Mines figures.

** Amount appropriated for state departments taken from figures of the Association of American State Geologists.

OPERATIONS

Information

Several means are employed by the Division of Mines for serving the state as an information bureau: (1) Personal interview and answering questions over the telephone; (2) correspondence; (3) providing technical library and reading room facilities; (4) providing educational exhibits on minerals, geology, and mining; (5) distribution, gratis, of information circulars; (6) distribution of publications on exchange basis to libraries and surveys; (7) distribution through sale, at cost of printing only, of publications to individuals.

Approximately 15,000 persons visit the San Francisco headquarters office each year, many of them to view the large exhibit of minerals on display. A visitors' register, which has been provided for many years, contains addresses from every state in the Union and many foreign countries. Many special groups, such as the Sierra Club, Boy Scouts, classes from various schools, also make visits to the Division. The majority of the visitors, amounting to 10,000 yearly, are seeking information concerning mines, minerals, geology, or related subjects. The time of one engineer-geologist is entirely taken in answering questions, and other engineers and geologists must help on special points, so that in the aggregate the equivalent of the time of two technical persons is required for this information service. Letters amount to 17,000 per year, and 7,000 publications are sold annually. Laboratory determinations of unknown minerals amounted to 2033 samples during the 98th fiscal year.

At the Los Angeles office, the number of telephone calls is particularly heavy, amounting to 7,800 per year; the number of visitors is approximately 8,000. The number of letters answered per year is 1,500. The information service takes the full time of one engineer. In addition, 2,500 publications are sold.

At Sacramento, requests for information, both oral and written, amount to about 3,000 per year, and at Redding to 1,400. At Sacramento, some 800 publications are sold during a year.

Library

The technical library is now undergoing reorganization and cataloging. It contains approximately 7,500 volumes covering the fields of mineralogy, geology, mining, metallurgy, and mineral economics. It is a collection of textbooks, government and state documents, technical journals, maps, and pictures, all particularly valuable to persons seeking information regarding the mineral industry. A trained librarian who is also a graduate geologist is in charge. New material is secured through exchange, gift, and purchase. The first donation was made in 1880. Thereafter the library steadily has grown. Subscription is made to 26 magazines. Donations of other serials, periodicals, and government reports constitute 75 percent of the material acquired. Thirty-two newspapers published in mining centers are placed in the reading room with the technical magazines and trade journals. It is estimated that 30 persons per day use the reading room.

There are at present 67 concerns in California on the exchange list; 126 California libraries and 92 out-of-state and foreign libraries receive our publications.

The accessions to the library during the 98th fiscal year are summarized in the following lists:

BOOKS (Letter symbols ------------------------------------ { D — Donation) E — Exchange)

D 1. Fanning, L. M., Our oil resources, McGraw-Hill, 1945.
D 2. Jones, P. J., Petroleum production, vol. 1, New York, Reinhold, 1946.
D 3. Liddell, D. M. and others, Handbook of nonferrous metallurgy, 2 vols., 2d ed., McGraw-Hill, 1945.
D 4. Rhodes, F. H., Technical report writing, McGraw-Hill, 1941.
D 5. Smith, C. V. and others, 6 Reprints from "Asbestos", Philadelphia, Asbestos.
D 6. Stokley, J., Electrons in action, New York, Whittlesey House, 1946.
D 7. Strack, L. H., Asbestos, a magic mineral, New York, Harper, 1941.
D 8. Tarr, W. A., Introductory economic geology, 2d ed., McGraw-Hill, 1938.
9. Parker, Chas. M., The metallurgy of quality steels, Reinhold, 1946.
D 10. DeGolyer, E. and Vance, Harold, Bibliography on the petroleum industry: Agric. and Mech. College of Texas Bull., 4th ser., vol. 15, no. 11, Sept. 1, 1944.
11. Witt, J. C., Portland cement technology, Chem. Pub. Co., 1947.
12. Parkes, G. D. and Mellor, J. W., editors, Mellor's modern inorganic chemistry, Longmans, Green and Co., Rev. ed. 1939.
13. McCullough, C. B. and McCullough, J. R., The engineer at law, 2 vols., Iowa State College Press, 1946.
14. American Institute of Mining and Metallurgical Engineers, Basic open-hearth steel making, 1944.
15. Annotated bibliography of economic geology, general index, vols. 1-10, 1928-1938, Econ. Geol. Pub. Co., 1939.
D 16. DeMent, J. and Dake, H. C., Rarer metals, Chem. Pub. Co., 1946.
D 17. Engle, N. H., editor, Marketing in the West, Ronald Press Co., 1946.
E 18. Daly, R. A., The floor of the ocean, Univ. North Carolina Press, 1942.
D 19. Stiles, Walter, Trace elements in plants and animals, Macmillan, 1946.
D 20. Gibb, T. R. P., Jr., Optical methods of chemical analysis, McGraw-Hill, 1942.
D 21. Rickard, T. A., The romance of mining, Toronto, Macmillan Co. of Canada, Ltd., 1947.
D 22. Chambers' technical dictionary edited by C. F. Tweney and L. E. C. Hughes, rev. ed. with supp., Macmillan, 1944.
D 23. Wright, William, The big bonanza . . . by Dan de Quille, A. A. Knopf, 1944.
D 24. Harte, Bret, Tales of the gold rush, New York, Heritage Press, 1944.
D 25. Scherer, J. A. B., Thirty-first star, G. P. Putnam's Sons, 1942.
D 26. Fenton, C. L. and Fenton, M. A., The rock book, Doubleday, 1946.
D 27. ------------ ------------, The story of the great geologists, Doubleday, Doran & Co., 1945.
D 28. Fenton, C. L., Our amazing earth, Doubleday, Doran & Co., 1946.
D 29. Kraus, E. H. and Slawson, C. B., Gems and gem materials, 4th ed., McGraw-Hill, 1941.
D 30. Twenhofel, W. H. and Shrock, R. R., Invertebrate paleontology, McGraw-Hill, 1935.
D 31. Young, Geo. J., Elements of mining, 4th ed., McGraw-Hill, 1946.
D 32. Hager, Dorsey, Practical oil geology, 5th ed., McGraw-Hill, 1938.
D 33. Uren, L. C., Petroleum production engineering—oil field development, 3d ed., McGraw-Hill, 1946.
D 34. Petroleum World annual review, 15th ed., 1947.
D 35. Turner, Bernice C., The private secretary's manual . . . rev. ed., Prentice-Hall, 1946.
D 36. California Railroad Commission and California Division of Oil and Gas estimate of the natural gas reserves of the State of California as of January 1, 1946, San Francisco, 1946.
D 37. U. S. Bureau of the Census, Statistical abstract of the United States, 1946.
D 38. U. S. 80th Congress, Official Congressional Directory . . . corrected to February 14, 1947.
D 39. U. S. Government Printing Office, Style manual, rev. ed., January 1945, Washington D. C., 1945.
D 40. U. S. Government Information Service, United States Government Manual 1947, 1st ed. . . . rev. to December 1, 1946.
D 41. Kalichevsky, V. A. and Stagner, B. A., Chemical refining of petroleum, rev. ed., Reinhold, 1942.
D 42. Li, K. C. and Wang, C. Y., Tungsten, 2d ed., Reinhold, 1947.

D 43. Murphy, ____________, Gold mines and mining in California . . . San Francisco, G. Spaulding and Co., 1885.
D 44. Wilcox, J. K., Public documents and World War II, Chicago, American Library Assoc., 1942.
D 45. Thiele, Walter, Official map publications, Am. Library Assoc., 1938.
46. Webster's collegiate dictionary, 5th ed., G. & C. Merriam Co., 1947.
47. Webster's new international dictionary of the English language, 2d ed., G. C. Merriam C., 1947.
D 48. Gable, J. H., Manual of serials work, Am. Library Assoc., 1937.
D 49. American Institute of Mining and Metallurgical Engineers, Transactions, vols. 104, 111, 159, 161, 162, 163, 164.
D 50. U. S. Bureau of Standards, Standards and specifications for nonmetallic minerals and their products, Misc. Pub. No. 110, April 1930.
51. Stanford University: Contribution from the Department of Geology, Stanford University, vol. 1, 1-4, 1930-1936.
E 52. American Association of State Highway Officials, Standard specifications for highway materials and methods of sampling and testing, 1938.
D 53. Mudge, I. G., Guide to reference books, 6th ed., Am. Library Assoc., 1936.
D 54. Wilcox, J. K., Manual on the use of state publications, Am. Library Asso., 1940.
D 55. Hirshberg, H. S. and Melenat, C. H., Subject guide to U. S. Government publications, Am. Library Assoc., 1947.
D 56. Mexico Secretaria de Agricultura y Fomento's Atlas Geographico de la Republica Mexicana, 1919-21.
D 57. Hawkins, A. C., The book of minerals, Wiley, 1935.
D 58. Simons, Theodore, Compressed air, McGraw-Hill, 1914.
D 59. Grout, F. F., Petrography and petrology, McGraw-Hill, 1932.
D 60. Young, Geo. J., Elements of mining, 3d ed., McGraw-Hill, 1932.
E 61. Gillette, H. P., Rock excavation, methods and cost, New York, M. C. Clark, 1904.
E 62. ____________ ____________, Earthwork and its cost, 3d ed., McGraw-Hill, 1920.
E 63. Dawson, J. W., Acadian geology, 3d ed., London, Macmillan and Co., 1878.
64. Chemical Industries Buyers' Guidebook number, 22d annual revision.
65. MacRae's Blue Book, vol. 54, 1947, Chicago, MacRae Blue Book Co., 1947.
66. Engineering Index, 1946, New York, Engineering Index, Inc., 1947.

GOVERNMENT BULLETINS (federal and state), TECHNICAL JOURNALS, TRADE MAGAZINES, FOREIGN PUBLICATIONS, MAPS, ETC. (These accessions have been acquired largely through exchange). Number of receipts approximate. Announcements, etc. not counted.

U. S. Geological Survey	
Bulletins	12
Professional Papers	9
Water-Supply Papers	32
U. S. Bureau of Mines	
Reports of Investigations	162
Information Circulars	38
Mineral Trade Notes	24
Miscellaneous U. S. Government office publications	20
Publications from mining departments and geological surveys of the several states of the United States	142
Publications from 34 domestic societies and educational institutions	300
Receipts of 49 trade periodicals and house organs	650
Foreign publications (governments, societies, and educational institutions)	320
Maps (separates, principally geologic)	10
Mining machinery catalogs, brochures, etc.	30
Library of Congress catalog cards	1,100

Exhibits

The mineral exhibit of the Division of Mines, which is one of the outstanding collections of its kind in the United States, steadily grows by donations. Accessions made to the exhibit during the 98th fiscal year are:

21237 CHRYSOCOLLA ($CuSiO_3.2H_2O$), hydrous copper silicate. From Contact, Nevada. Donor: Charles B. Foster and Boyd Wood, July 1946. In case 139.

21238 MARMATITE (FeS-ZnS), a ferriferous sphalerite with CHALCOPYRITE. From Mattie ore body of Mountain Copper Company's Hornet mine, Matheson, Shasta County, California. Donor: Walter W. Bradley, August 1946. In case 106.

21239 CHROMITE ($FeCr_2O_4$), high grade, from Gray Pit lease of McLaughlin-Applegarth, Tehama County, California. Donor: Walter W. Bradley, August 1946. In case 235.

21240 CHROMITE ($FeCr_2O_4$), banded disseminated, from McLaughlin-Applegarth lease on school land, west of Red Bluff, on North Fork of Elder Creek, Tehama County, California. Donor: Walter W. Bradley, August 1946. In case 235.

21241 CHALCOPYRITE ($CuFeS_2$), from Gray Eagle copper mine, Siskiyou County, California. Donor: Walter W. Bradley, August 1946. In case 233.

21242 IRON ORE, a mixture of HEMATITE and LIMONITE. From Vulcan iron mine, Kelso, San Bernardino County, California. Donor: Walter W. Bradley, August 1946. In case 226.

21243 CASSITERITE (SnO_2), in calcite, from Evening Star mine near Cima, San Bernardino County, California. Donor: Walter W. Bradley, August 1946. In case 226.

21244 MANGANESE ORE, from Staneuch mines, San Luis Obispo County, California. Donor: Walter W. Bradley, August 1946. In case 228.

21245 CHROMITE ($FeCr_2O_4$), high grade, from French Hill mine, Del Norte County, California. Donor: Walter W. Bradley, August 1946. In case 205.

21246 SILVER-GOLD ORE, from Palisade mine near Calistoga, Napa County, California. Donor: Walter W. Bradley, August 1946. In case 218.

21247 CINNABAR (HgS), in calcite, from sec. 31, T. 18 S., R. 5 E., M.D., Monterey County, California. Donor: Walter W. Bradley, August 1946. In case 218.

21248 LAVA (vitrophyre), from Lake Albert, Lake County, Oregon. Donor: Walter W. Bradley, August 1946. In case 503.

21249 STIBNITE (Sb_2S_3), with gold and silver, from Oro y Plata mine, near Murphys, Calaveras County, California. Donor: Walter W. Bradley, August 1946. In case 204.

21250 GRANODIORITE from Lower Minaret Creek, Madera County, California. Donor: Walter W. Bradley, August 1946. In case 501.

21251 GRANITE, porphyritic with large crystals of ORTHOCLASE feldspar in a medium-granular groundmass. From upper Middle Fork of Stanislaus River on Sonora Pass road, California. Donor: Walter W. Bradley, August 1946. In case 501.

21252 GRANITE, porphyritic with large euhedral crystals of ORTHOCLASE feldspar in coarse-grained groundmass. From above Tenaya Lake, Yosemite National Park. Donor: Walter W. Bradley, August 1946. In case 501.

21253 ANDESITE (old lava, prior to 1914 eruption), showing both fine- and coarse-grained phases. From top of Lassen Peak. Donor: Walter W. Bradley, August 1946. In case 503.

21254 PUMICE (1915 eruption), from devastated area northeast side of Lassen Peak. Donor: Walter W. Bradley. August 1946. In case 503.

21255 DACITE (spongy phase), from throat of crater of 1915 eruption, Lassen Peak. Donor: Walter W. Bradley, August 1946. In case 503.

21256 DACITE (1915 eruption), altered by fumarolic action in crater of Lassen Peak since eruption. Donor: Walter W. Bradley, August 1946. In case 503.

21257 ARSENIC, native in QUARTZ. From Alcalde mine, west of Grass Valley, Nevada County, California. Donor: Lloyd L. Root, August 1946. In case 212.

21258 ROSE QUARTZ, cut specimen shows asterism.

21258-D ROSE QUARTZ. Near Chilcoot on Plumas-Lassen County Line. Donor: Harry E. Chaffee, August 1946. In cases 617 and 222.

21259 TANTALITE-COLUMBITE in LEPIDOLITE, from near Gunnison, Colorado. Donor: P. B. Burtt, August 1946. In case 140.

21260 SPHALERITE, rich in cadmium and rare metals such as germanium and indium. Specimen fluoresces and is triboluminescent. From Plomositas mine, near Pichacos, Chihuahua, Mexico. Donor: Dan M. King, August 1946. In case 257.

21261 SHATTUCKITE ($2CuSiO_3.H_2O$), from New Cornelia mine, Ajo, Arizona. Donor: C. E. Bronson, August 1946. In case 139.

21262 ANGLESITE ($PbSO_4$) associated with GALENA and CERUSSITE. Well developed crystals of anglesite in cavities in the galena. Found at Darwin mines of Anaconda Mining Company, Darwin, Inyo County, California. Donor: Anaconda Mining Company, August 1946. In case 147.

21263 GALENA (PbS) in STRONTIANITE. Found on property of Rex Mining Company, Mesquit mining district, Virgin Mountains, Mohave County, Arizona. Donor: John C. P. Skottowe, August 1946. In case 307.

21264 SELENITE GYPSUM, showing fish-tail twin crystals. Found near Silver City, New Mexico. Donor: J. M. Forbes, October 1946. In case 248.

21265 CLAY, high aluminum. From Ione, Amador County, California. Donor: Walter W. Bradley, October 1946. In case 202.

21266 HERCYNITE (an iron spinel, $FeAl_2O_4$) in well-developed crystal. Found at Seward Peninsula, Alaska. Donor: S. A. Montague, October 1946. In case 117.

21267 WILLEMITE (green) from Franklin, New Jersey. Donor: John C. P. Skottowe, October 1946. In case 806.

21268 WILLEMITE (green), CALCITE (red) with FRANKLINITE from Franklin, New Jersey. Donor: John C. P. Skottowe, October 1946. In case 806.

21269 CALCITE (red) in RHODOCHROSITE from Franklin, New Jersey. Donor: John C. P. Skottowe, October 1946. In case 806.

21270 WERNERITE (yellow) from Ontario, Canada. Donor: John C. P. Skottowe, October 1946. In case 806.

21271 ONYX (chalcedony) from Manhattan mine, Knoxville, Napa County, California. Donor: John C. P. Skottowe, October 1946. In case 806.

21272 BRECCIA cemented with CALCITE. From Calico Mountains, San Bernardino County, California. Donor: John C. P. Skottowe, October 1946. In case 806.

21273 FOSSIL SHELLS from Wyoming. Donor: John C. P. Skottowe, October 1946. In case 806.

21274 FOSSIL EQUISETUM from near Ludlow, San Bernardino County, California. Donor: John C. P. Skottowe, October 1946. In case 806.

21275 FLUORITE from near Ludlow, San Bernardino County, California. Donor: John C. P. Skottowe, October 1946. In case 806.

21276 CALCITE (white) from near Ludlow, San Bernardino County, California. Donor: John C. P. Skottowe, October 1946. In case 806.

21277 DOLOMITE (red) said to be from Calico Mountains, San Bernardino County, California. Donor: John C. P. Skottowe, October 1946. In case 806.

21278 CALCITE (ghost crystal, fluoresces red) from near Ludlow, San Bernardino County, California. Donor: John C. P. Skottowe, October 1946. In case 806.

21279 FLUORITE. Donor: John C. P. Skottowe, October 1946. In case 806.

21280 ONYX (aragonite) from east slope of Panamint Mountains, Inyo County, California. Donor: John C. P. Skottowe, October 1946. In case 806.

21281 PECTOLITE from first cut along highway north of Middletown, Lake County, California. Donor: R. F. Henley, October 1946. In case 617.

21282 ONYX MARBLE (aragonite) from Cement, Solano County, California. Donor: R. F. Henley, October 1946. In case 617.

21283 MYRICKITE (cinnabar in chalcedony) from Manhattan mine, Knoxville, Napa County, California. Donor: R. F. Henley, October 1946. In case 617.

21284 GOLD IN QUARTZ. Found at Lanky Bob mine, 5 miles east of Sawyers Bar, Siskiyou County, California. Donor: Harry Docker, November 1946. In case 233.

21285 PYROPHYLLITE ($H_2Al_2Si_4O_{12}$) from Matthews deposit 2 miles northeast of Rancho Santa Fe on Escondido road, San Diego County, California. Donor: C. R. King, November 1946. In case 139.

21286 CALCITE (iceland spar) in exceptionally large well-developed crystal from Barranca de Cobre (grand canyon of the Urique River), southwest of Creel, Chihuahua, Mexico. Donor: C. R. King, November 1946. In case 120.

21287 AGATE (chalcedony) with iron hydrate inclusions, from near San Luis Obispo, San Luis Obispo County, California. Donor: Gordon Bowser, January 1947. In cases 617 and 228.

21288 GUMBELLITE (white fibrous), hydrous potassium and aluminum silicate. From Jurupa Mountains, San Bernardino County, California. Only known occurrence in the United States. Donor: R. A. Crippen, January 1947. In case 135.

21289 WOLFRAMITE (polished set in ring of tin-antimony alloy). From Kiangsi Province, China. Donor: S. H. Dolbear, January 1947. In case 702.

21290 HEULANDITE on drusy QUARTZ with orange-colored calcite. From Sowerbutt (Vandermade) quarry, near Patterson, New Jersey. Donor: T. Orchard Lisle, January 1947. In case 134.

21291 GARNETS in QUARTZ and MICA SCHIST. From Brooklyn-Manhattan vehicular tunnel. Donor: T. Orchard Lisle, January 1947. In case 129.

21292 Ruby MUSCOVITE MICA, No. 1 grade, 12 inches by 18 inches. An exceptionally fine specimen of sheet mica. From Saracura mine, Municipality of Bicas, State of Minas Geraes, Brazil. Donor: William C. McCulloch, February 1947. In case 135.

21293 Ruby MUSCOVITE MICA, No. 1 grade. From Santa Clara mine, Municipality of Bicas, State of Minas Geraes, Brazil. Donor: William C. McCulloch, February 1947. In case 135.

The Division of Mines supplied 12 sets of 40 minerals each to high schools and junior colleges during this last year. Loans were made, as for example to Stix, Baer, and Fuller in St. Louis, Missouri; special exhibits were contributed, as for example, to a mining meeting in Madera, California; and five county fairs were supplied with a judge for their mineral displays.

Information Circulars

Improvement has been made in the various mimeograph releases issued by the Division of Mines. All releases are now consolidated into three: (1) Commercial Mineral Notes; (2) Information Circulars; (3) Announcements of New Publications. Once a month these are assembled and each set sent out under one cover to all addresses on the mailing lists; they now total over 3000. The mailing lists have now been overhauled so as to include all persons who purchase our publications and who indicate a desire to receive the releases. In this way the small operators, prospectors, and persons desiring information are served regularly; much letter writing is avoided by providing these persons with current news and general information; sale of the publications has been noticeably increased by this procedure.

Publications

The most important and permanent information service of the Division of Mines is its distribution of publications. Public libraries are made depositories of the publications, which are thus made available to persons all over the world. The following list indicates the reports published, in press, and processed for publication during the 98th fiscal year:

Reports Published

(Those marked GS were contributed by U. S. Geological Survey)

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 42, January 1946.
- Geology of Santa Rosa Mountain Area, Riverside County, California, by Lawrence B. Wright.
- Geology and Nickel Mineralization of the Julian-Cuyamaca Area, San Diego County, California, by S. C. Creasey. (GS)
- Tin Deposits of the Gorman District, Kern County, California, by John H. Wiese and Lincoln R. Page. (GS)
- California's Minerals for Tomorrow, by Walter W. Bradley.

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 42, April 1946.
- Quicksilver Deposits of the New Idria District, San Benito and Fresno Counties, California, by Edwin B. Eckel and W. B. Myers. (GS)
- Quicksilver Deposits at the Sulphur Bank Mine, Lake County, California, by Donald L. Everhart. (GS)

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 42, July 1946.
- Mines and Mining in Tehama County, by J. C. O'Brien.
- Quicksilver Deposits of the Western Mayacmas District, Sonoma County, California, by Edgar H. Bailey. (GS)
- Quicksilver Deposits of the Eastern Mayacmas District, Lake and Napa Counties, California, by Robert G. Yates and Lowell S. Hilpert. (GS)
- Minerals at "The Geysers", Sonoma County, California, by M. Vonsen.
- Observations at "The Geysers", Sonoma County, California, by Walter W. Bradley.

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 42, October 1946.
The Map Information Office of the Geological Survey, by C. F. Feuchsel. (GS)
Geology of the Kramer Borate District, Kern County, California, by Hoyt S. Gale.

BULLETIN 129—IRON RESOURCES OF CALIFORNIA.
Part K—Shasta and California Iron-Ore Deposits, Shasta County, California, by Carl A. Lamey. (GS)

BULLETIN 131—CONSOLIDATED INDEX OF PUBLICATIONS, DIVISION OF MINES AND STATE MINING BUREAU, 1880-1943, by Walter W. Bradley.

BULLETIN 133—GEOLOGY OF THE SAN JUAN BAUTISTA QUADRANGLE, CALIFORNIA.
Geology of the San Juan Bautista Quadrangle, California, by John Eliot Allen (including geologic quadrangle, scale 1:62500).
Operations of the Granite Rock Company Quarry and Plant at Logan, San Benito County, by Royal E. Fowle.

BULLETIN 135—PLACER MINING FOR GOLD IN CALIFORNIA, by Charles V. Averill.

Reports in Press June 30, 1947

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 43, no. 1, January 1947.
Walibu Quicksilver Mine, Kern County, California, by Edgar H. Bailey. (GS)
Mines and Mineral Resources of Lake County, California, by Charles V. Averill.
Mines and Mineral Resources of San Benito County, by Charles V. Averill.
Condenser Installation at the New Idria Quicksilver Mining Company, Idria, California, by Richard A. Crippen.

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 43, no. 2, April 1947.
Mines and Mineral Resources of Stanislaus County, by Abbott Charles.
Vanadium, by W. B. Winston.
Fifty Years of Operations in Shasta County by The Mountain Copper Company, Ltd., by William F. Kett.

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 43, no 3, July 1947.
Limestone in California, by C. A. Logan (in part).
Status of Topographic Mapping in the United States, by Map Information Office of the U. S. Geological Survey. (GS)

BULLETIN 129—IRON RESOURCES OF CALIFORNIA.
Part O—Summary of Investigations of Iron-Ore Deposits of California, by A. C. Johnson and Spangler Ricker.

BULLETIN 137—CALIFORNIA MINERAL PRODUCTION AND DIRECTORY OF MINERAL PRODUCERS FOR 1945, by Henry H. Symons.

Reports Processed for Publication

Limestone in California, by C. A. Logan (in part).
Mines and Mineral Resources of Siskiyou County, California, by J. C. O'Brien.
Pumice, by W. B. Winston.
Silver, by W. B. Winston.
Kingston Mountains Iron-Ore Deposits, San Bernardino County, California, by D. F. Hewett. (GS)
Titaniferous Iron-Ore Deposits of Western San Gabriel Mountains, by Gordon B. Oakeshott.
Bibliography of Iron-Ore Deposits of California, by Elisabeth L. Egenhoff.
Minerals of California, by Joseph Murdoch and Robert W. Webb.

Ore Buyers License

The work of the Ore Buyers Inspector has steadily increased since Order L-208, which restricted gold mining, was rescinded. The number of ore buyers licenses issued in 1947 showed a slight increase over the number issued during the 98th fiscal year. The Ore Buyers Inspector spent 112 days in the field, making 398 contacts with ore buyers, mine operators and informants. One arrest was made and a conviction secured in which the defendant was sentenced to 2 years in the Federal Prison and fined $3,000.00.

Technical Reorganization

The reorganization of the Division of Mines to form two principal branches has effected greater administrative efficiency, improved the quality and increased the output of work, and has resulted in a better integration of different phases of the problems involved. In the Mining Engineering Branch, the section on Minerals Economics has undertaken the study of markets, uses, specifications, and processes, as well as statistics of the minerals produced in California. A market directory has been established and many inquiries on this subject are now satisfactorily answered.

In the Geologic Branch, the section on mineralogy has greatly improved the identification of samples sent in by the public. A much-needed mineral commodity survey has been initiated.

Cooperative Projects

The Division of Mines actively cooperates with the departments of geology in several universities with the result that many excellent reports and maps have been issued, other are in press, still others are in preparation as reported under the heading "publications."

An agreement has been made with the U. S. Bureau of Mines to test certain massive copper-zinc ores to determine if a method can be designed to improve recovery of these metals from their complex occurrence.

For the past 2 years the Division of Mines has carried on cooperative work with the U. S. Geological Survey. Each agency was designated to contribute $50,000 per year, the money to be matched on a fifty-fifty basis for "a cooperative investigation of the geology of the State of California." The following report has been submitted by the U. S. Geological Survey and summarizes the activities of the program.

CALIFORNIA COOPERATIVE INVESTIGATIONS IN GEOLOGY

(A Report Contributed by the U. S. Geological Survey)

"Fiscal 1947 was the second year of geological surveys in California under the cooperative program of the United States Geological Survey and the State Division of Mines. Expenditures for the year amounted to $68,747.94, compared with $34,900.30 in fiscal 1946, each agency providing half. The reason for these expenditures being substantially less than the total of $100,000 per year which, under the cooperative agreement, the two agencies were to provide, was that, because of numerous reconversion problems through most of the two years, it was impossible to assemble a full staff of qualified personnel. At the end of fiscal 1947, however, the rate of work was approximately at the full level possible under the joint appropriations, for then the program was engaging the full time of 16 geologists and one clerk, and the part-time services of three geologists and temporary assistants, a total of 20 members of the Geological Survey.

"The immediate and principal object of the work is to collect, interpret, and distribute geologic information of value to those directly engaged in producing and using the mineral raw materials of California. The work will also yield, over a long range, much basic data of value to all who are concerned with the reserves of minerals in California, the economics of its mineral industry, the occurrence of its mineral deposits, and the fundamental problems of California geology.

"Since the geology of California is diversified and complex, this investigation of the geology of its mineral deposits consists of detailed scientific surveys in several districts that are widely separated in the state and that yield a variety of mineral products. To take full advantage of much intensive work that the Geological Survey did during the war, the cooperative program is carrying to completion two major war-time investigations, one in the New Almaden quicksilver district, and the other in the Bishop tungsten district, and two smaller investigations in the Gasquet chromite and the Neenach tin districts. Another major investigation is also based on incomplete war-time work of much less intensity; this is the Cerro Gordo-Ubehebe

lead-zinc investigation. Major investigations that were initiated under the program include a new, detailed survey of the Mother Lode gold deposits, an investigation of the Shasta copper belt, and an investigation of the San Diego pegmatite deposits, once a prominent source of feldspar, lithium minerals, and gem stones.

"It will be noted that metallic ores are the main mineral products of most of the districts being studied, their non-metallic materials being a minor product, or presenting a less critical geological problem, or being of a type for which no trained specialist is yet available. Non-metallic materials are the chief product only in the San Diego pegmatite district. Non-metallic materials will receive a larger share of the work in the future.

"The first two years seem to show, as expected, that there are substantial advantages in having the work done as a cooperative enterprise. The larger scale of work possible under the joint appropriation is only part of the story. In general planning and in the selection of districts to be studied, the Supervising Geologist (now Chief) of the State Division of Mines makes an important contribution; he also provides proper coordination with the work of the Division of Mines and with the research of California geologists such as members of universities, and he supplies an intimate knowledge of the California mineral industry. The Geological Survey provides trained and fully equipped specialists for the work and supplements their individual efforts with appropriate supervisory and consultant services of other specialists (e. g., six consultants visited field parties during fiscal 1947). In addition to these direct activities in the field, the Geological Survey provides, as required, technical and scientific services from its laboratories and research groups in Washington and elsewhere. The work under the cooperative program is coordinated with other Geological Survey work in California that is supported entirely by Federal funds.

"In fiscal 1947 geological investigations were made in 10 mineral districts, which are described below. In three minor districts field work was completed and in the others, all major projects, the work is continuing. In general, each investigation of a major district is to include a thorough study of the geology of the area surrounding the mineral deposits. Most of these surveys of areal geology will cover, in considerable detail, one or more quadrangle sheets on a scale of 1 inch equal 2,000 feet. In addition, all accessible mines and known mineral occurences in the districts will be examined in much greater detail."

Active Projects, June, 1947

(U. S. Geological Survey Cooperative Work)

"*Shasta Copper Belt.* The areal geology of approximately the eastern half of the Weaverville 15-minute quadrangle has been mapped, and the mapping is being extended northeastward along the copper belt. Detailed mapping of the Iron Mountain deposit, surface and underground, began in the spring of 1947. (Geologists A. R. Kinkel Jr. and J. P. Albers).

"*Mother Lode Gold Deposits.* The areal geology of the Mother Lode belt has been mapped (approximately 10 miles), north and south of the Stanislaus River, and is being extended outward and northward from the strip. (Geologists J. H. Eric, A. Stromquist, C. M. Swinney, and G. R. Heyl).

"*New Almaden Quicksilver District.* The areal geology is essentially complete for the northeastern third of the New Almaden quadrangle, and detailed maps have been finished for the surface and underground workings of the principal deposits. (Geologists E. H. Bailey, D. L. Everhart, and D. F. Kupfer).

"*Bishop Tungsten District.* Three 15-minute quadrangles are to be mapped in the area, which includes the Pine Creek tungsten deposit and many smaller ones. Most of two quadrangles are finished. The mining areas were nearly all covered in detail during the war. (Geologists Paul Bateman, M. W. Ellis; Field Assistant J. E. Reid).

"*Cerro Gordo-Ubehebe Lead-Zinc District.* Areal geology of two 15-minute quadrangles is nearly half completed, and the geology of the Cerro Gordo mining district is three-fourths finished. (Geologists C. W. Merriam, Ward C. Smith, and J. F. McAllister).

"*San Diego Pegmatite Districts.* Detailed maps of the pegmatite deposits of the Pala district are completed and areal geology of vicinity is three-fourths finished. (Geologists R. H. Jahns, J. B. Hanley, and W. E. Hall)."

Field Work Completed, Fiscal 1947)
(U. S. Geological Survey, Cooperative Work)

"*Gasquet Quadrangle.* A reconnaissance map of the Gasquet 15-minute quadrangle rounded out the work done there in the course of war-time studies of chromite deposits. (Geologists F. G. Wells, F. W. Cater).

"*Neenach Quadrangle.* Areal geology of the Neenach 15-minute quadrangle was surveyed in order to complete war-time investigations made there in the vicinity of small deposits of tin. The report on the quadrangle is being processed for publication. (Geologist J. H. Wiese).

"*Cuyamaca Peak Quadrangle.* The areal geology of the Cuyamaca Peak quadrangle was nearly completed before the war and completion of it in fiscal 1947 was included in the cooperative program, with all but $500 of the cost of the work borne by the Geological Survey. (Geologist D. L. Everhart)."

PLANS FOR THE FUTURE, 99TH FISCAL YEAR

The following work has been planned for the 99th fiscal year in the Division of Mines:

Mining Engineering Branch

1) Mineral Economics Section

To expand the regular statistical volume to include a discussion on (a) mineral resources, (b) markets.

To start a series of reports on ''Marketing California Minerals'' covering (a) specifications, (b) industries using each mineral, (c) information on buyers.

2) District Mining Engineers

To start field work on general reports covering ''mines and mineral resources'' of the following counties: Alameda, Inyo, Madera, Santa Barbara, Sonoma, and Tuolumne. A report on current activities in the mineral industries of the Redding district will be prepared also. As soon as personnel is available, work will be started on reports on Fresno and Tulare Counties, for which requests have been received. Work will also be started on San Diego County granites.

Geologic Branch

Preparation, in cooperation with the Mineral Economics Section, of general mineral commodity reports for current information circulars.

Preparation of state-wide detailed mineral commodity reports on the following: pumice, perlite, talc and steatite, and asbestos.

Preparation of geologic guide maps and guidebook of the Sierran gold belt.

Completing and processing of detailed commodity mineral reports on the following: iron, copper, chromite, quicksilver, and magnesite, which are in large part contributed.

Completing and processing geologic maps and reports on the following quadrangles: Tesla, Blue Lake, Lake Elsinore, Hollister, Copperopolis, St. Helena, and Nipomo.

Table 4. ***Value of total recorded mineral production by substances to and including 1945***

Mineral products in order of total value to 1945	Year of first recorded production	Total value to 1945	Value of 1945 output	Year of peak value	Year of peak output	Order of principal producing counties in 1945	Remarks
Petroleum	1875	$6,979,121,880	$342,756,767	1926	1945	Kern, Los Angeles, Fresno	California's output exceeded only by that of Texas The value of the state's output of petroleum exceeds total of all other mineral products.
Gold	1848	2,254,573,446	5,177,830	1852	1852	Nevada, Sacramento, Yuba	California led nation in output for many years, until 1941. During war years most of the mines were closed down. In 1945, passed by Utah.
Cement	1891	597,087,401	23,469,027	1942	1942	San Bernardino, Santa Clara, Riverside	California led nation in output in 1944.
Natural gas	1888	572,138,437	35,362,313	1945	1945	Sacramento, Los Angeles, Solano	Output only exceeded by Texas in 1944.
Stone, miscellaneous (sand, gravel, crushed rock)	1893	455,191,034	20,207,351	1942	1942	Alameda, Los Angeles, Sacramento	Leads nation in sand and gravel output in 1944.
Copper	1882	195,872,163	1,883,206	1916	1908	Siskiyou, Shasta, Calaveras	Shasta County led in output from 1897-1918; Plumas from 1919-40; Siskiyou from 1941-44.
Brick and hollow tile	1893	169,467,541	3,523,661	1923		Los Angeles, Contra Costa, Sacramento	One of the important structural materials.
Sandstone	1887	4,674,491	7,498	1903	1904	Monterey, Ventura, Napa	Demand has greatly decreased in recent years.
Bituminous rock	1887	4,633,048	*	1888	1910	Santa Cruz, Santa Barbara	A possible future source for petroleum products.
Dolomite	1915	4,441,434	*	1944	1944	Monterey, Tuolumne, San Benito	Output increased greatly with its use in the reduction of magnesia from sea water.
Bromine	1926	4,057,206	*	1944	1944	San Bernardino, Alameda, San Diego	Fourth in output among states in 1944.
Bentonite	1899	3,622,073	*	1928	1928	San Bernardino, Inyo	Ranks high among the states in total output.
Marble	1887	3,586,220		1909		Tuolumne (in past)	Marble is being replaced by artificial stone as terrazzo
Pumice and volcanic ash	1909	3,137,357	461,022	1945	1945	Modoc, Madera, Kern, Inyo	Leads all states in total value (1944).
Barite	1910	2,871,415	*	1945	1945	Mariposa, Plumas, Nevada	Ranks high among the states in total output.
Gems	1900	2,625,407	*	1943		Imperial, Santa Clara	Includes optical minerals. Production irregular.
Molybdenum ore	1916	1,855,483		1943	1943	Inyo	Fourth as to quantity mined in 1944.
Carbon-dioxide gas	1894	1,462,626	*	1944	1944	Imperial, Mendocino	California is an important source of natural carbon dioxide.
Calcium chloride	1921	1,363,753	*	1926	1926	San Bernardino	Second as to value of output in 1944.
Slate	1889	1,363,742	*	1906		El Dorado, Placer	
Platinum metals	1887	1,185,973	6,719	1941	1941	Sacramento, Yuba, Stanislaus	Platinum metals are a by-product from gold placers.
Lithia	1899	1,074,023	*	1945	1945	San Bernardino	Third in nation 1944. Recent from brines of Searles Lake.
Magnesite	1887	19,290,994	*	1917	1917	Santa Clara	Natural mineral is being replaced by magnesia made from sea water.
Lead	1877	16,362,225	1,247,410	1917	1917	Inyo, San Bernardino, Mariposa	Lead production has shown a steady increase since 1935 with Darwin district, Inyo County, as chief producer.
Pyrite	1898	15,302,267	*	1909	1909	Shasta	Second among the states (1944).
Zinc	1906	14,532,034	2,224,184	1945	1926	Mariposa, Calaveras, Shasta	California's output stimulated by war.
Chromite	1869	12,902,622	431,445	1918	1918	Del Norte, Tehama, San Luis Obispo	California's output was first among the states (1944).
Magnesia	1916	12,539,852	*	1944	1944	Monterey, San Mateo, Alameda	Ranks third among the states (1944).
Gypsum	1887	11,204,524	954,696	1945	1944	Riverside, Kern, Imperial	Ranks third among states (1944).
Talc, pyrophyllite, and soapstone	1893	8,538,688	922,682	1945	1945	Inyo, San Bernardino, Mono	Second in value of output (1944).
Silica (sand, quartz)	1899	8,002,211	1,309,564	1945	1945	Monterey, San Bernardino, San Diego	Leads nation in output of quartz and ranks high in sand (1944).

Iron ore	1881	7,172,890	883,434	1944	1945	San Bernardino, Shasta, Santa Cruz	With completion of Fontana steel plant in 1942, production showed a marked increase.
Iodine	1929	7,055,535	*	1943	1943	Los Angeles	Only state producing.
Paving blocks	1887	5,712,288		1912	1912		Has been replaced with smooth paving.
Manganese ore	1887	5,124,616	86,270	1944	1944	San Luis Obispo, Trinity, Humboldt	1944 output only surpassed by Montana and Nevada
Quicksilver	1850	144,538,250	2,697,835	1943	1877	San Benito, Sonoma, Yolo	Leads nation with approximately 70% of output (1944).
Borates	1864	140,038,049	5,898,823	1937	1937	Kern, San Bernardino, Inyo	World's principal source.
Potash	1914	78,407,646	*	1944	1944	San Bernardino	Output only surpassed by New Mexico (1944).
Silver	1880	71,857,213	701,723	1921	1921	Inyo, Mariposa, Calaveras	Usually by-product in mining for other metals.
Soda (soda ash and salt-cake)	1894	47,353,251	3,793,571	1945	1945	San Bernardino, Inyo	Leads nation in natural sodium salts.
Diatomite	1889	43,031,445	*	1945	1944	Santa Barbara, Los Angeles	Principal United States source.
Tungsten ore	1905	42,677,457	1,587,951	1943	1943	Inyo, San Bernardino, Fresno	Output passed by Idaho only in 1944.
Salt	1887	42,523,019	2,030,226	1944	1944	Alameda, San Bernardino, San Diego	Most California salt obtained from solar evaporation of sea-water.
Mineral water	1887	39,469,482	798,430	1930	1930	Los Angeles, San Bernardino, Marin	Represents that which is bottled for sale.
Granite	1887	29,309,660	220,441	1925		Inyo	Dimension stone in recent years cannot compete with concrete.
Lime	1894	24,311,890		1941	1941		1941 on included under limestone.
Limestone	1894	24,101,426	1,626,844	1945	1944	San Bernardino, Tuolumne, El Dorado	For industrial purposes, not including that used in cement.
Clay (pottery)	1887	23,507,414	1,345,966	1928	1928	Kern, Riverside, Orange	California is important source
Coal	1861	23,400,166	*	1880	1880	Trinity	Since 1900 has dropped to only a few tons per year.
Feldspar	1910	1,065,925	*	1928	1928	San Bernardino	
Sillimanite-andalusite-kyanite group	1922	968,659	*	1926	1926	Mono, Imperial	Ranks first in output of andalusite.
Sulphur	1865	829,399		1941	1941	Inyo, Alpine (in past)	Production intermittent. Large deposits of possible grade.
Grinding-mill pebbles	1915	357,389	*	1916	1917	San Diego	Output irregular and small.
Mineral paint	1880	248,958	*	1893	1903	San Bernardino	Recent intermittent and irregular.
Antimony	1887	226,071		1916	1916		Output not important and is intermittent.
Strontium	1916	210,222	*	1943	1943	Imperial, San Bernardino	Second in nation. A war mineral (1944).
Asbestos	1887	164,967	*	1910	1921	Shasta, Napa	Value of output third in nation in 1944.
Titanium	1927	159,080		1928	1928	Los Angeles	Small output.
Mica	1902	133,674	*	1944	1945	Imperial	Production irregular and intermittent.
Onyx and travertine	1887	122,219		1894			(See Marble). Production irregular and intermittent.
Shale oil	1922	109,500		1924		Santa Barbara (in past)	Possible future source for petroleum oils.
Graphite	1901	87,495		1918	1918		No output in recent years.
Tin	1891	62,534		1892	1892		Several occurrences are known in state (1944).
Serpentine	1895	33,259		1896	1895	Los Angeles (in past)	New plant using serpentine in fertilizer now in operation.
Garnet (abrasive)	1939	24,795	*	1945	1945	Inyo	Output intermittent; demand limited.
Calcium silicate	1933	23,854		1938	1938	Kern	First recorded commercial production in United States in 1933.
Cadmium	1917	16,489		1917	1917		Material reported was a by-product from zinc.
Fluorspar	1917	8,912		1944	1944	Riverside	Output intermittent.
Bismuth	1904	2,400					In 1942 some bismuth concentrates were made but no shipments reported.
Arsenic	1924	1,356					Output only reported in 1924.
Zircon	1937	1,310		1941		Placer (in past)	Small amounts of zircon are found in most black sands.
Alum minerals	1938	160		1938		Riverside (in past)	
Total recorded value to 1945		$12,188,531,894					
Total value of 1945 output			$473,661,591				

*Figure appears only in total because this substance was reported by less than three producers.

Table 5. California counties in order of total value of recorded mineral production

County	Year of first recorded output	Rank of output in 1945	Value of total output	1945 value of output	Principal minerals in order of total value
Los Angeles	1880	2	$3,109,579,901	$103,641,827	Petroleum, natural gas, miscellaneous stone
Kern	1880	1	2,148,479,810	126,716,079	Petroleum, natural gas, gold
Orange	1889	4	940,488,932	35,178,471	Petroleum, natural gas, miscellaneous stone
Fresno	1880	3	642,641,849	51,677,246	Petroleum, natural gas, miscellaneous stone
Ventura	1880	5	526,126,352	29,352,740	Petroleum, natural gas, miscellaneous stone
San Bernardino	1880	6	442,699,827	23,038,011	Cement, potash, borates, silver
Kings	1894	8	257,111,308	13,568,174	Petroleum, natural gas, quicksilver
Nevada	1880	23	237,961,709	1,196,433	Gold, silver, miscellaneous stone
Shasta	1880	19	205,742,851	2,119,802	Copper, gold, silver
Amador	1880	33	152,194,290	487,544	Gold, pottery clay, miscellaneous stone
Sacramento	1880	9	144,703,969	9,240,880	Gold, natural gas, miscellaneous stone
Riverside	1891	13	139,621,051	4,644,406	Cement, miscellaneous stone, brick
Calaveras	1880	16	129,082,677	2,789,881	Gold, copper, cement
Santa Clara	1850	11	115,430,842	5,810,388	Quicksilver, cement, miscellaneous stone
Inyo	1880	14	114,631,441	4,258,250	Tungsten ore, soda, lead, gold
Yuba	1880	24	109,612,225	1,186,139	Gold, miscellaneous stone, silver
Alameda	1890	10	103,221,506	6,661,939	Miscellaneous stone, salt, brick
Santa Cruz	1894	20	98,088,849	2,015,407	Cement, lime, bituminous rock
Plumas	1880	55	82,018,915	41,243	Copper*, gold, silver
Butte	1880	29	77,526,508	663,610	Gold, miscellaneous stone, silver
Contra Costa	1894	17	74,470,369	2,496,533	Cement, miscellaneous stone, brick
Solano	1873	12	70,500,642	5,282,725	Cement*, natural gas, miscellaneous stone
Placer	1880	42	60,400,280	241,359	Gold, miscellaneous stone, pottery clay
San Benito	1865	21	59,994,276	1,949,386	Quicksilver, cement, miscellaneous stone
San Mateo	1895	18	55,781,028	2,363,508	Cement, miscellaneous stone, salt
Tuolumne	1880	35	55,666,156	434,626	Gold, limestone, miscellaneous stone
Sierra	1880	47	53,101,709	172,782	Gold, miscellaneous stone, silver
Siskiyou	1880	27	50,790,380	926,305	Gold, copper, miscellaneous stone
Trinity	1875	50	48,180,097	91,560	Gold, quicksilver, manganese ore
Napa	1862	30	44,113,413	628,974	Quicksilver, miscellaneous stone, mineral water
El Dorado	1880	39	43,507,299	301,627	Gold, limestone, miscellaneous stone
San Diego	1880	26	42,820,137	1,142,350	Miscellaneous stone, gold, brick
Santa Barbara	1881	7	33,743,847	22,643,580	Petroleum, diatomite, natural gas
Mono	1880	49	33,064,219	91,928	Gold, silver, andalusite
Mariposa	1880	25	30,624,022	1,171,094	Gold, miscellaneous stone, barite
Merced	1880	40	29,276,847	258,363	Gold, cement*, miscellaneous stone
San Joaquin	1885	22	26,915,560	1,256,594	Natural gas, brick, miscellaneous stone
Lake	1873	44	21,219,660	197,448	Quicksilver, mineral water, miscellaneous stone
Sonoma	1873	28	20,940,714	807,122	Miscellaneous stone, quicksilver, mineral water
Stanislaus	1880	36	20,250,106	406,727	Gold, miscellaneous stone, manganese ore
Monterey	1889	15	17,836,151	3,018,280	Miscellaneous stone, magnesia, dolomite
Madera	1893	46	15,508,344	189,886	Granite*, gold, copper
San Luis Obispo	1876	31	14,986,244	497,923	Quicksilver, miscellaneous stone, chromite
Marin	1888	32	14,230,651	491,435	Miscellaneous stone, brick*, mineral water
Tulare	1880	41	14,153,210	256,764	Magnesite*, miscellaneous stone, tungsten ore
Humboldt	1880	43	12,376,282	201,514	Miscellaneous stone, gold, brick
Imperial	1907	37	11,196,027	383,431	Miscellaneous stone, gold*, gypsum
San Francisco	1894	51	8,693,922	75,172	Miscellaneous stone, brick*, mineral water
Del Norte	1880	38	5,512,808	341,306	Miscellaneous stone, chromite, gold
Colusa	1875	57	4,084,315	7,083	Sandstone*, mineral water*, miscellaneous stone
Glenn	1893	52	3,661,970	72,046	Miscellaneous stone, chromite*
Yolo	1873	34	3,434,588	479,810	Quicksilver, miscellaneous stone, natural gas
Lassen	1880	56	2,587,780	20,635	Gold*, miscellaneous stone, granite
Mendocino	1880	48	2,086,839	118,767	Miscellaneous stone, manganese ore*, carbon dioxide
Modoc	1880	45	1,889,557	193,156	Miscellaneous stone, gold*, pumice
Tehama	1880	53	1,739,621	69,921	Miscellaneous stone, chromite, mineral water*
Sutter	1908	54	700,956	62,910	Natural gas, pottery clay, miscellaneous stone*
Alpine	1880	58	369,974	1,500	Gold, silver, miscellaneous stone

*None reported produced in 1945.

THE MINERAL INDUSTRY OF CALIFORNIA

Significance of the Mineral Industry of California

In table 3, California stands third among the states of the Union for mineral output in 1945. In 1946 the value of mineral production in California was larger than that of any preceding year, with a record production both in amount and value reported for gypsum, lead, limestone, pumice and volcanic ash, talc and soapstone, soda (soda ash and salt cake), salt, silica (quartz and glass sand), barite, calcium chloride, iodine, lithium minerals, potash, and serpentine. All-time records in total values were recorded for petroleum and natural gas although in 1945 the quantity produced was greater. The value of borates also reached a new high and 1946 tonnage was exceeded only in 1937. The 1946 production of cement and miscellaneous stone was exceeded in quantity and value only by that of 1942.

Table 4 shows the salient and significant features of the state's mineral production. Table 5 indicates how each county in the state contributes to this production.

Mineral Industry of California in 1947 *

Introduction

The recent accelerated shift to California of both population and industry has caused an intensified building boom in this state, accompanied by a tremendous demand for the materials used in construction.

* Compilation by Charles V. Averill, Supervising Mining Engineer, and Olaf P. Jenkins, Chief, California State Division of Mines. Manuscript submitted for publication July 29, 1947.

Raw products necessary to make the structural materials include minerals and rocks; the critical shortage of lumber is causing substitution by mineral products. The cement mills of California are running near capacity, and the state is now leading all others in production of this ingredient of concrete. This means that the production of crushed rock, sand, and gravel necessary for aggregate is also at a high level. Other mineral raw materials that are in high demand for building are clay for brick and tile, gypsum for plaster and wall-board, and pumice for light-weight aggregate in concrete and building blocks. The artificial pumice known as perlite, for which volcanic glass is the raw material, will probably soon be produced in quantity.

Among mineral raw materials demanded in large quantities by the expanding industries of California is limestone, which is used in flux in smelting metals, in agriculture, in mortar, plaster, glass, fruit-sprays, water-purification, sugar-refining, manufacture of paper, and in many smaller industries. Soda ash used in glass and soap, and as a chemical in the manufacture of many other products, is in very high demand; new plants are being built at Searles Lake, a new one has been completed at Owens Lake, and the demand still exceeds the supply. Other industrial minerals, the production of which continue at a high level, include borates for use in glass, enamels, drugs, and many other products; bentonite and barite used in oil-well drilling-muds; diatomite for filtration and insulation; iodine for drugs and chemicals; potash for fertilizer; and talc for paints, ceramics, toilet preparations, and insecticides.

California depends for fuel upon her enormous deposits of petroleum and natural gas rather than upon coal, more commonly used elsewhere. Annual production of petroleum in California is many times as great in value as that of any other mineral substance, and the 1947 production is expected to be the greatest on record. Although new discoveries are being made in the state, supply is not keeping up with demand, and some petroleum is being imported. Natural gas is in such high demand that a 30-inch pipe line is being constructed to bring this fuel from Texas to California.

The condition of the metal-mining industry in California shows a mixed trend. The production of metals is not rising in the same measure as that of most structural and industrial minerals. The new pig-iron industry at Fontana continues to run at capacity, and new facilities are being added for the manufacture of additional types of steel. Production of lead, particularly at Darwin, Inyo County, continues at essentially the same rate as during the war. Tungsten mining, however, almost ceased after the war because of the drop in price, but now the price is rising, and the industry is reviving. Quicksilver production is low because of the low price of the metal. Output of copper and zinc is low, largely because known reserves were depleted during the war. Some development of new reserves is under way. Aluminum and magnesium were both produced in California during the war, but the plants have been closed. Gold mining was all but shut down during the war by order of the War Production Board, and the output is still low, but is rising. Manganese production has dropped to a low level.

Details of the condition of the mineral industries in 1947 appear on the following pages.

Aluminum

Though the high-grade clays of the Eocene of California occur in enormous quantity, the grade is insufficiently high in alumina to attract prospective companies to attempt operating on the basis of making aluminum from these clays.

Raw material for aluminum production in California has been imported from other states because commercial deposits of the ore, bauxite, have not yet been found in California.

During the war aluminum was produced in two large plants in California, owned by the United States Government, one at Riverbank and the other at Los Angeles (Torrance). The possibility exists that these plants will be reopened by private capital, providing power can be obtained at a rate low enough to make the operation economic. Demand for aluminum for building and other purposes continues to be high during 1947.

Antimony

Known deposits of antimony in California are small; ores occur in Inyo, Kern, Orange, San Benito, and San Bernardino Counties, whence small amounts occasionally have been produced. In the past 2 years small shipments running 40 to 50 percent antimony have been made from Inyo and Kern Counties to Harshaw Chemical Company, El Segundo, California; but during 1947 no antimony is being produced.

The increase in the price of antimony ore, 50 to 55 percent, to $4.00 to $4.10 per unit of antimony contained, may lead to development of deposits in the counties mentioned.

Asbestos

Although minute stringers and veinlets of chrysotile asbestos occur throughout the serpentines of northern California, production of short-fiber chrysotile asbestos has been very limited in this state. This type of asbestos—the variety that can be woven into fabrics such as asbestos curtains, asbestos clothing, and brake linings—is supplied the United States largely by Canada. The largest tonnages find their way into the building trades for such manufactured products as sheeting, wall board, shingles, pipe covering, and boiler covering. California is not producing this type of asbestos at the present time, but sales of short-fiber chrysotile asbestos were made from a property in Napa County in 1945.

Though the fibers of amphibole asbestos are too brittle for weaving into fabrics, this variety can be used industrially since it is resistant to acid. A small tonnage of amphibole asbestos is in constant demand for filtering acids. Properties in Shasta and Placer Counties are producing the type called tremolite asbestos.

Barite

California has a number of important barite deposits, and is an important producer of barite. Barium chemicals which are manufactured in California use raw material imported from Nevada; but most of the barite mineral produced in California finds its way into drilling muds. At the present time the principal production is coming from Mariposa and Plumas Counties. Another deposit is being developed in Tulare County, and reserves probably exist in both Nevada and Shasta Counties.

3—76940

Barite is a mineral of high specific gravity that is used mainly for giving weight to mud used in the drilling of oil wells. The mud controls the pressure of gas and otherwise facilitates drilling.

Barite that is white when finely pulverized is used as a pigment, but most of the barite so used is given chemical treatment to convert it into lithopone. The mineral is also used in the glass and rubber industries and for the manufacture of a number of barium chemicals.

Bentonite

Bentonite is produced chiefly from large deposits in San Bernardino, Inyo, Kern, and San Diego Counties. The principal production in southern California is for oil drilling mud used in the petroleum industry.

From 1935-46, production averaged about 11,000 tons per year. With increase in the amount of drilling in the various oil fields in California, an increased production of bentonite should result. Other uses are increasing with the industrial development of southern California.

Principal producers are Baroid Sales Division, National Lead Company; Kennedy Minerals Company; Sierra Talc Company; Pacific bentonite mine; Standard Oil Company of California; F. C. Schundler & Company.

Bituminous Rock

Present production of bituminous rock is from Santa Cruz County. The rock is a sandstone containing natural asphaltic material which fills the spaces between the sand grains, thus forming a cement. A few thousand tons have been marketed each year for many years as road dressing. Much larger tonnages of asphalt are produced as a by-product at oil refineries for use on roads.

Research on such asphaltic materials is quite likely to develop additional uses in the future, as for example, the production of light aggregates. Also, research may result in the extraction of petroleum products from mined bituminous sands. Large quantities occur in various localities in the state, such as near Santa Maria and south of San Luis Obispo.

Borates

The reserves of borate minerals in California are enormous, making this state the world's greatest source. Production of borates in California in 1947 is well up to or above the average for the past 8 or 9 years. Banner years of production were 1936 and 1937. After war was declared in Europe, loss of foreign markets, especially Germany, a large consumer, caused a decrease. However, in the last 4 years production has been normal, in spite of the many difficulties imposed by the war, and is now showing a steady increase.

Of the five producers in the state, three extract borate salts from the brines of Owens and Searles Lakes; the other two mine borate minerals from underground, where they occur interstratified in lake sediments.

The Pacific Coast Borax Company's mine at Kramer is highly mechanized, using slushers and mechanical loaders in all working places. The American Potash & Chemical Company, the West End Chemical Corporation and the Pittsburgh Plate Glass Company, all pump brines from the lakes into their plants, where the brines are handled mechanically; hence this industry has not been affected severely by the high cost of labor.

Bromine

Bromine has been produced in California on a tonnage basis during every year since 1926. The sources are sea bitterns, recovered after the production of common salt from sea water; and the brines of Searles Lake, which are treated primarily for potash, soda, and borax.

The principal use of bromine is for the manufacture of ethylene dibromide, which in turn is used in the manufacture of tetraethyl lead for improving gasoline by means of its knock-inhibiting property.

Building Stone

Immense reserves and a large variety of building stones occur in California. Granite, marble, sandstone, slate, diorite, granodiorite, and numerous volcanic rocks, including tuff, have been quarried in the state in large amounts for buildings and monuments. Years ago, dimension stone was used in buildings to the amount of roughly $1,000,000 annually, but this use has been largely displaced by concrete construction. Most of the granite now quarried is used for monuments and comes from Fresno, Lassen, Placer, San Bernardino, and San Diego Counties. Small amounts of marble are produced in San Luis Obispo and San Bernardino Counties. Large reserves of this stone still exist in many other counties. Sandstone and various types of volcanic rocks that break into flat slabs are in considerable demand for flagstone, garden construction, and decorative veneers on the fronts of buildings. Many such stones have a distinctive color, which adds to the value. Such stone is produced in Napa, Monterey, and Santa Barbara Counties.

Calcium Chloride

Production of calcium chloride in California amounts to 10,000 tons per year. The output represents a by-product from the extraction of salt and other salines from sea water and from inland dry lakes.

California's output in recent years has come from the salt deposits on Bristol Lake near Amboy, San Bernardino County, from Salton Sea near Niland, and sea water brines at Chula Vista, San Diego County. The demand for calcium chloride is limited and any increase in production is therefore not expected. Producers are California Rock Salt Company, Amboy, California; Hill Brothers Chemical Company, Amboy, California; Mullett Island Salt Works, Niland, Imperial County.

Calcium Silicate

Large deposits of wollastonite, or calcium silicate, occur in California. One in particular occurs in the Rademacher district near Randsburg, Kern County, owned by the Johns-Manville Corporation, but only occasional shipments are made from this deposit to the company's plant in Los Angeles. Here it is used in the manufacture of rock wool for insulation. Increased production during 1947 is possible.

Carbon Dioxide

Carbon dioxide produced during 1946 came from wells operated by one company near Niland, Imperial County, and by one company near Hopland, Mendocino County. Recent production is at the rate of about 200,000 M cubic feet of carbon-dioxide gas per year, which is com-

pressed to make about 13,000 net tons of dry ice, valued at more than $250,000. Cardox Western, Inc., of Los Angeles acquired National Dry Ice Company's plant and wells in 1944. Natural Carbonic Products, Inc., suspended operations June 30, 1944. Because of the limited area of the carbon-dioxide field in the region about Niland, and suspension of operations of one of the companies, little possibility exists for an increase in production during 1947. However, there is a notably increasing demand for carbon dioxide for use in the refrigeration of foodstuffs and in the transportation of cut flowers.

Cement

In 1947, California is leading all states in both the production and consumption of portland cement, and the mills are operating at a fairly high percentage of their rated capacity. The total (all-time) value of cement produced in this state is exceeded only by the total value of petroleum and gold.

Production is rising because of the high level of construction activity: large buildings, houses, highways, bridges, and aqueducts. The manufacture of concrete blocks for the building industry as a substitute for lumber is expanding rapidly, and large quantities of portland cement are used. Many blocks are made with a pumice aggregate to achieve light weight. These are described elsewhere in this report.

Portland cement is made by heating to incipient fusion an intimate and finely pulverized mixture of argillaceous and calcareous materials. The resulting clinker is finely pulverized and approximately 3 percent of its weight in gypsum is added. The calcareous raw material is usually limestone, but oyster shells and marl are used also. The argillaceous material is clay or shale containing silica, alumina, and iron. Mills are usually located near centers of population so that heavy transportation charges can be avoided. California mills are equally divided between the southern and northern parts of the state, six mills in each part. Production in the state is considerably higher than consumption, and cement is available for export. Raw material for portland cement is abundantly available in many places in California for the expansion of the industry if that becomes desirable.

Chromite

Chromite is widely distributed in the serpentine rocks which occur abundantly in the Coast Ranges, Klamath Mountains, and Sierra Nevada of California. The high-grade ores occur chiefly in "lenses" or "kidneys" which are very irregular in shape and size. For this reason little ore is developed ahead of production and few deposits are developed or equipped for low-cost mining. The lower-grade ores occur as banded and disseminated deposits; they are quite extensive in Glenn, El Dorado, and Siskiyou Counties, but the grade of chromite that can be mined from them is too low to meet the specifications for metallurgical-grade ores. The United States Bureau of Mines has developed a process for making electrolytic chromium from these low-grade ores, and metallic chromium is used to make low-carbon, chrome-steel alloys in the electric furnace. Prices being offered for chrome ore in 1947 are such that only a few small producers remain in business. Most of the recent production has come from Del Norte County.

Clay

Clay is the raw material used in making a great variety of articles including common brick, sewer tile, decorative tile, dinnerware, and table china. All of these and many similar products are manufactured in California. Because of California's large increase in population, the change in this industry has been very marked since the end of the war. During the war the industry was considered non-essential and hence was operating at a low level.

Clay suitable for common brick is found at widely scattered points throughout California and is available at reasonable distances from centers where the population is sufficient to consume the output of a brick plant. Such plants ranging in size from small to large are scattered all over California. The wide availability of this type of clay keeps the prices down and precludes transportation for long distances.

Clays of higher grade, suitable for such products as fire brick and dinnerware, are found at three main centers, Ione in Amador County, Lincoln in Placer County, and Alberhill in Riverside County. All of these are remnants of deposits of clay hundreds of feet thick that were laid down in inland seas many millions of years ago when the climate of the region was semi-tropical. Prolonged decay of rock formations on the land furnished the material.

The various strata have a wide range in properties, and are kept separate in mining. In places, strata of very good silica sand are interbedded and are mined commercially. The usual method of mining is by stripping and then benching in open pits to expose the various strata, but some underground mining is used for strata of very high grade, such as fire clays and china clays.

The great demand for housing and other types of buildings includes demand for brick for walls and chimneys, for sewer tile, floor tile, and wall tile, for sanitary ware, and for tableware. Hence the clay industry continues to expand in 1947.

Coal

The production of coal in California has considerable historical significance. The coal was produced chiefly from the Mount Diablo district in Contra Costa County and the Tesla district in Alameda County, but smaller amounts were mined in Amador, Fresno, Monterey, Orange, Riverside, Shasta, Siskiyou, and Trinity Counties. Reserves are estimated to be more than 100 million tons, those of Mendocino and Shasta Counties alone having been estimated at 35 million tons. The coal is classed as non-coking bituminous, sub-bituminous, and lignite.

Coking coal is imported from Utah and the by-products produced in the coking process offer competition to similar products which could be produced from California coals. The competitive position of our coal may improve as the supplies of petroleum and natural gas are depleted, as the demand for fuels increases with the expansion of industry, and as the population continues to increase.

Constant improvements are being made in the machines, methods, and equipment for mining, processing, and utilizing coal. Flat coal beds are stripped and mined with power shovels. The sink and float process, jigs, and classifiers, have made it possible to produce clean coal from beds having many shale partings. Burners using powdered coal,

mechanical stokers, and briquetting machines have created a market for grades of coal previously unsaleable. Experiments are being made to determine the feasibility of producing gas by the controlled combustion of coal beds in place, and manufacturing gasoline, fuel, and lubricating oils from coal. These developments indicate that the coal deposits of California may some day be an important source of industrial fuel. In 1947, a deposit in Amador County is being developed and equipped to produce coal. Also, a very small production of coal has recently been made in Trinity County.

Copper

Most of the copper now being mined in California is in the form of a complex heavy sulfide containing much pyrite, much zinc sulfide, and a little lead. Separation of these minerals is made by the flotation process, but the recoveries of the individual metals leave much to be desired. Improvements in this process would help to increase profits from the mines. The process is expensive because extremely fine grinding is necessary.

The principal producers of this type of ore are the Mountain Copper Company, Ltd., Shasta County, and the Penn mine in Calaveras County. The Gray Eagle in Siskiyou County and the Keystone in Calaveras County, which were important producers during the war, have been shut down.

Copper production in California during 1947 is at a low ebb chiefly because of war-time depletion of known reserves. The mines that are still operating are dependent for a profit on premiums paid by the United States Government, and these may or may not be continued after July 1, depending on legislation now before the Congress. Future production in California probably depends upon the making of new discoveries and such discoveries may not be made until better methods are available, such as improved combinations of geological and geophysical surveys.

Like all other underground metal mines, copper mines are hampered by present high cost of labor. This is being combated by mechanization of the mines, such as substitution of mechanical shoveling or slusher scraping for hand shoveling. Productivity of labor is being increased by incentive-pay systems, such as a bonus for footage above a fixed amount in driving development headings. Special methods of mining designed to produce ore with a minimum of all kinds of shoveling are also being adopted. Some labor has been saved in the past by the substitution of diamond-drill blast holes for those drilled by the conventional steel bits. However, the recent introduction of drill-bits with inserts of tungsten carbide may restore the use of conventional drilling machines.

Diatomite

California is the world's most important source of diatomaceous earth, a light, porous, chalk-like material, composed of silicious remains of microscopic plant life. By far the largest production in the United States comes from a deposit at Lompoc, Santa Barbara County. The deposit second in importance in California is in the San Pedro Hills, Los Angeles County. Other deposits are located in Contra Costa, Fresno, Inyo,

Kern, Monterey, Orange, Plumas, San Benito, San Bernardino, San Joaquin, San Luis Obispo, Shasta, Sonoma, and Tehama Counties.

Distribution of uses for diatomite are about as follows:

	Percent
Filtration	50
Insulation	25
Fillers	20
Miscellaneous	5

Annual production from 1927-47 has been in excess of 150,000 tons. During the recent war, diatomite producers were handicapped because exportation was cut off. In 1946, an increase in the production of diatomite was noted, although operating companies were hampered by the shortage of labor. An increase in production during 1947 is probable as companies resume shipments of both filtration and insulation material to foreign markets.

The producers have installed power shovels and modern labor-saving devices to cut labor costs and combat scarcity of labor. Principal producers are Johns-Mansville Corporation, owner and operator of Lompoc deposits, Santa Barbara County; Great Lakes Carbon Company, which purchased the Dicalite Company's deposit in Los Angeles County; and Lompoc Diatomite Company, Lompoc, Santa Barbara County.

Feldspar

At present, most of the feldspar used in California is shipped from Arizona and Nevada deposits, where large and exceptionally pure deposits are worked, and favorable freight schedules allow competition with known California deposits. Formerly productive deposits of feldspar in California are in the following counties: Fresno, San Bernardino, San Diego, Inyo, Plumas, Riverside, Contra Costa, and Monterey. Undeveloped or partly developed deposits are known in many other counties. The shift of industry to the Pacific Coast, coupled with accelerated population growth and demand for manufactured products, may bring about the reopening of the idle California feldspar deposits, and development of new deposits. The demand may make practicable the application of ore-dressing methods to the concentration and processing of feldspar, and the profitable operation of many medium-grade deposits now idle.

Total production of all classes of feldspar in the United States is at the rate of approximately 325,000 tons per year of an average value of about $2,000,000. Over 95 percent of the production is used in various branches of the ceramic industry; over 50 percent of the production is used in the glass industry alone. The manufacture of enamels, and high grades of pottery, chinaware, and porcelains demand about 40 percent of the production.

Garnet

Very large potential reserves of garnet exist in California, principally in the pegmatites and in tactite areas associated with tungsten ores in the central and southern parts of the state. A small and intermittent production is made, amounting to less than a thousand tons per year in California, all of which is used as an abrasive sand in tumbling-barrels or sand blasting. The airplane manufacturing industry is the principal consumer. Most of the garnet produced in the state is recovered from mill tailings produced in the concentration of tungsten ore, and the production of

garnet except as a by-product resulting from the beneficiation of other minerals has not been economic. The average selling price for sized garnet for sand blasting is from $16.00 to $18.00 per ton.

Research into new uses and markets for garnet may result in a greatly expanded demand as the industrialization of California proceeds. Garnet should make an ideal aggregate for concrete factory floors subject to shock and abrasion, and should find a much wider application in sand blasting, in the manufacture of abrasive papers, and other allied fields where its hardness and toughness are advantageous. The tactites or garnet rocks of California are not as brittle as the crystalline garnet of the Appalachian region.

Gold

Billions of dollars worth of recoverable gold undoubtedly still remain in veins and ancient placer deposits in California. That California has always been a gold-mining state is well known throughout the world; but the demand for industrial minerals, increasing with growth of population, is fast overshadowing the older more romantic mining industry.

California's gold mines with few exceptions were shut down during the war by Limitation Order L-208 of the War Production Board, which was in effect from October 8, 1942 to July 1, 1945. In 1944 production of gold dropped to $4,108,055, the lowest since 1848, the year in which Marshall discovered gold at Sutter's saw mill. The 1940 production of $50,948,485 is in sharp contrast. Other factors tending to shut down the gold mines were in effect even before October 1942, such as rising cost of labor and supplies and the policy of the Government in diverting labor from gold mines to war industry; hence, some of the gold mines had already closed when the Limitation Order of the War Production Board was issued.

The period of idleness caused great damage to many of the mines in the form of caved and flooded workings. High prices of labor and materials and high taxes in 1947, together with fixed price of gold of $35.00 per ounce, are discouraging to operators of underground mines, and many of these mines remain closed.

Dredging properties, particularly those equipped with connected-bucket dredges, were much less affected than the underground mines, and deterioration was slight. Properties equipped with dragline dredges were adversely affected because the dragline excavators were in demand for war work, both as excavators and as cranes, and were scattered and worn out on such work. The washing plants, like the connected-bucket dredges, were not adaptable to war work and remained on the placer-mining properties.

In 1947 the industry is slowly reviving, but such factors as high cost of labor and supplies and scarcity of both are still retardants. Extensive repair jobs on caved workings are necessary in some of the mines. Persons responsible for management of the few large underground mines that are reopening must use every possible device to increase the output of labor, such as incentive-pay systems and more extensive mechanization. For instance, hand-shoveling must be considered in the luxury class from the standpoint of management, and every effort must be made to move ore and waste either by gravity or with mechanical shovels and scrapers. Incentive-pay brings the miner a larger day's wage for a larger day's work and makes his earnings comparable to those of other skilled trades.

Development work is active at a number of small lode mines, where an effort is being made to find new ore bodies.

Dragline dredging is also rather slow to revive, chiefly because dragline excavators are in short supply, hard to get, and high in price. The cost of labor on a dragline dredge forms a higher percentage of total cost of operation than on a connected-bucket dredge; hence present high cost of labor is a factor in holding back the revival of dragline dredging.

Connected-bucket dredges are resuming production as fast as crews can be assembled and machinery repaired. On most of these dredges machinery is intact, and only maintenance work is needed to put them back in operation. Cost of labor is only about 20 percent of total cost in this type of gold production, contrasted with 50 percent in underground lode mining; hence dredging with connected-bucket dredges is affected less by high wages. Dredging of this type is being revived at a higher rate than other types of gold mining.

Gypsum

Production of gypsum in California for the year 1947 will probably equal or exceed the all-time high of 618,007 tons in 1946. The tremendous growth of gypsum production, from 70,833 tons in 1935 to the 1946 high, received much of its impetus in the early years of this period from increase in agricultural uses. More recently, however, its use in building materials, such as hard-wall and other plasters, wall board, and cement has surpassed that for agricultural purposes.

A large part of the agricultural gypsum is produced in the San Joaquin Valley, where it is excavated by scrapers, after removal of a small overburden, loaded directly into trucks, and delivered to the farm lands on which it is to be used. Shipments of this material are also being made from eastern Riverside County. This is a stable industry, which may be expected to continue at its present rate of production or with a gradual increase, as more farmers learn of the advantages of using gypsum.

Most of the gypsum for industrial use comes from Imperial and Riverside Counties and is marketed in the form of manufactured products. That used in the manufacture of cement in southern California comes from Ventura County. Present rate of production of these materials will no doubt be maintained or increased during the building-boom period.

The largest producer of gypsum products in the state is the United States Gypsum Company, which in the last few years has increased the capacity of its plant at Midland, in eastern Riverside County, from 300 ton to 800 tons per day, although, owing to labor shortage, much of its production has been at the rate of 600 tons per day. This is all turned out as processed materials consisting of wall plaster, finishing and casting plaster, and manufactured products such as wall board and lath. This company also has purchased recently a deposit and a plant at Plaster City, Imperial County, from the Pacific Portland Cement Company, and is now engaged in doubling the capacity of this plant.

Iodine

Commercial production of iodine in California began in 1929, at which time a plant was put into operation for the extraction of this

material from waste water of oil wells. In 1933 two other plants were added, and recent production has been more than 500,000 pounds per year.

At present three plants are operating, and one is under construction, all in the Los Angeles area. The Great Western Division of Dow Chemical Company is operating a plant in the Venice field and one at Seal Beach, which was moved from Long Beach in 1939. This company is now constructing a plant in the Inglewood field. The Deepwater Chemical Company operates a plant in the Dominguez field. With the addition of the new plant, production for 1947 will undoubtedly exceed that for any preceding year.

Iron and Steel

Large deposits of high-grade iron ore have been known for many years to exist in California; but commercial production of pig iron actually began in this state January 1, 1943, when the blast furnace of the Kaiser Company's plant at Fontana was blown in. Since that time capacity production, 1200 tons of hot metal per day, has been maintained, with the exception of a short period immediately following the war. To January 1, 1947, 1,307,996 tons of hot metal had been produced. By far the greater part of the ore fed to this furnace came from the company-owned Vulcan mine, 9 miles south of Kelso in San Bernardino County. To January 1, 1947, this property had shipped 2,103,448 tons, always maintaining a minimum of 50 percent iron content. Operations will be discontinued July 1, 1947, and mining activities will be transferred to the Eagle Mountain deposits in eastern Riverside County. The Vulcan mine is being abandoned because the operators would either have excessive stripping costs or would have to go to expensive underground mining; and also on account of the increased sulphur content of the ore. By July 1 sufficient ore will have been stockpiled at Kelso and the Vulcan mine to carry furnace operations during the period of moving to the Eagle Mountain deposits.

The Eagle Mountain deposits have been drilled and trenched. This work developed 25,000,000 tons of blast-furnace-grade ore and it is estimated that an additional 45,000,000 tons can be made available by benefication. Development of this property includes the construction of a total of 51 miles of railroad, which will be built and operated by the company, and which is expected to be in operation by April 1948.

Other shipments of iron ore, in quantity, come from the Cave Canyon deposit of the California Portland Cement Company. This deposit is in San Bernardino County and supplies from 30,000 to 60,000 tons per year to the company's plant at Colton and the Riverside Cement Company's plant at Crestmore. No curtailment of these shipments is anticipated.

Total steel production in California in 1942, the year before the Fontana steel furnaces were started, was 1,041,046 tons. The open hearth section at Fontana consists of six 185-ton furnaces having a monthly capacity of 60,000 tons. These furnaces were put into operation in May 1943. To January 1, 1947, 1,950,000 tons of steel had been produced. Finishing facilities are as follows: plate mill with an annual rated capacity of 300,000 tons; structural mill with a capacity of 210,000 tons per year; merchant mill, 180,000 tons per year. In addition to these, construction is now in progress on the following: pipe mill to produce

125,000 tons annually; cold roll mill for light-weight strip 42,000 tons; cold draw plant 24,000 tons, rounds, flats, squares, and hexagonals.

Lead

There are important deposits of lead in the desert mountain ranges of California, especially in Inyo County; these occur as replacement deposits in Paleozoic or older limestones.

Increase in the price of lead to 14.8 to 15 cents per pound, together with a steady demand and diminishing stocks, place this metal in a very strong position. These conditions are responsible for increased activity in the exploration for and production of lead in California. The steady increase for the past 3 years is shown by the following statistics:

Year	Pounds	Value	Cents per pound
1944	11,408,381	$912,670	8
1945	14,448,000	1,242,528	8.58
1946	20,130,000	2,033,130	10

The 1946 production has been exceeded only once in the state's history. In 1917 the output was 21,651,352 pounds valued at $1,862,016 or 8.60 cents per pound. Present indications are that the 1947 production will equal if not exceed that of 1946.

Anaconda Copper Mining Company, operating at Darwin, produced more than three-quarters of the 1946 output and has recently increased the capacity of its concentrator. Most of the lead from Darwin ores is recovered by direct smelting. The Finley Company, operating Columbia No. 2 mine (formerly operated by Shoshone Mines Company) was the second largest producer in the state for 1946. This property is 9 miles east of Tecopa in Inyo County. Its production will be increased as a mill is now under construction for treatment of ores which could not be shipped. In the past all ore from this property has been shipped directly to the smelter. Dunton-Ray and Greenwood, shipping from the Mohawk mine in eastern San Bernardino County, were third in production.

Morris Albertoli and associates are doing development work on the Black Canyon (Mineral Point) mine in the White Mountains in Inyo County. Some ore has been shipped from the property and it appears that a substantial production may eventually be attained. Shipments of dump ores from the Santa Rosa mine in Inyo County are being made regularly to the smelter. Rehabilitation of this mine has been going forward, and shipments from the mine may be expected in the near future.

This upward trend in the production of lead in the state may be expected to continue as long as the price of the metal is sufficiently high to offset increased labor costs.

Lime and Limestone

In 1946, production of limestone in California broke all records. It is continuing at a high level in 1947. Deposits that are equipped for production are being operated at practically full capacity, and additional deposits are being equipped.

Limestone or dolomite occur in all but a few of the counties in California, but only about 10 counties are important producers. The complexity of the geologic structure of the state, together with the discontinuity and local variation of the magnesia-lime ratio, cause many

problems in both exploration and operation. In the Sierra Nevada, the limestones from Calaveras County to the south are likely to contain considerable magnesia. From Amador County to the north, the limestone is largely of the high-calcium variety. Recent sampling in Tuolumne County gave the following results from adjacent beds: for a width of 600 feet the limestone is high in calcium; for a width of 300 feet, 35.46 percent magnesium carbonate, 60.77 percent calcium carbonate. In four counties of the state, oyster shells are utilized as a substitute for limestone in poultry feeds and fertilizer, and for burning to lime. At the south end of San Francisco Bay, oyster shells dredged from the bay are used in the manufacture of portland cement. San Bernardino County and the Coast Range counties south of San Francisco are large producers of both limestone and dolomite. Shasta County is very abundantely supplied with limestone of three different geologic ages, but little is being done with it in 1947, although formerly large tonnages were used as flux at copper smelters.

Lime, which is made by heating limestone to drive off the carbon dioxide, is one of the most important industrial chemicals. Raw limestone also has many industrial uses, of which an example is flux in smelting ores for recovery of metals. Finely pulverized limestone is added to soils to reduce acidity, to supply calcium as plant food, and to improve certain soils in other ways. The largest tonnages of limestone go into the manufacture of portland cement, considered separately in this report, under the heading *Cement*. Small amounts of marble, a variety of limestone, are still used in the building industry, and this has been mentioned under the heading *Building stone*. In California, only small amounts of limestone are used as crushed rock in aggregate for concrete and in building roads. In a few industries such as the manufacture of soda-ash and the production of beet-sugar, both the lime and the carbon dioxide driven from the limestone to make lime are utilized in the process.

Lime is used in the open-hearth steel industry, in brick mortar, plaster, glass, stucco, fruit-sprays, water-purification, sugar-refining, manufacture of paper, and in many smaller industries. Dolomite lime, which is made by heating dolomite, the double carbonate of calcium and magnesium, is mentioned under the heading of magnesium salts. Much dolomite is used at open-hearth steel furnaces also.

Lithium

Lithium-bearing ores, lepidolite, amblygonite, and spodumene, are found in San Diego and Riverside Counties but no production was made in 1946. Aside from production of lithium from Searles Lake, the output will be small in 1947.

Lithium salts occur in the brines of Searles Lake near Trona, San Bernardino County. The by-product lithium is recovered by flotation as lithium-sodium phosphate, containing about 22 percent Li_2O, by the American Potash & Chemical Corporation. Production is limited by the size of equipment available to recover potash, borates, and soda, the main products.

Magnesium Compounds

The raw products for making magnesium compounds are unlimited in California: large deposits of magnesite, abundant undeveloped dolo-

mite deposits, sea water, and unlimited serpentine deposits, which may some day be utilized.

Magnesium metal was produced in California in large quantities during the war, both for castings and in powdered form for use in incendiary bombs. Two large plants that produced this metal are now shut down. Apparently new uses must be developed for this metal before its production in California will again become practicable.

On the other hand, the demand for compounds of magnesium is high. Dead-burned magnesia refractories are used in steel furnaces, and as the demand for steel is high, this use, which is the largest, continues high. Uses of the salts of magnesium include oxy-chloride cement for flooring, and other compounds for rayon manufacture and insulating materials. The hydroxide is used in pharmaceutical preparations, such as "milk of magnesia." The source of raw material has shifted from magnesite mined by underground methods to sea water, or the bittern that remains after solar evaporation of sea water, for the recovery of salt. Precipitation of magnesium hydroxide has, until recently, been made with lime derived either from pure limestones or from oyster shells. At present calcined dolomite is used instead of lime as the precipitant, because the magnesia content of the dolomite is added to the output of the plant.

The principal producers of magnesium compounds in California are Westvaco Chlorine Products Corporation, Alameda County; Permanente Metals Corporation, Monterey County; and Marine Magnesium Products Corporation, San Mateo County.

Manganese

Nearly 1000 manganese deposits are known from 44 of California's 58 counties. The most important producing counties in terms of total past production, are Alameda, Imperial, Mendocino, Plumas, Riverside, San Joaquin, San Luis Obispo, Santa Clara, Stanislaus, and Trinity Counties. Though some of the deposits have been largely mined out, many still contain sizable reserves of low-grade siliceous ore, which in the advent of another war, might prove attractive to the miner.

The deposits in southwest Stanislaus and southeast Alameda Counties, though relatively low in grade, during the past war proved to be desirable for making batteries. A plant was set up near Patterson, California, to beneficiate the ore, but it has now been dismantled and the machinery shipped away.

California in war time has been one of the principal producers of manganese in the United States. Between 1941 and 1944, California mined more than 50,000 tons of manganese and was exceeded in production only by the State of Montana. Most California manganese is relatively low in grade and high in silica, which makes it undesirable for normal uses, but during war time, when the demand for domestic manganese is high, manufacturers are less insistent upon peace-time specifications. Hence, with the rise in price, many manganese properties can be mined with profit. However with the return to normal peace-time activities the demand for California manganese has diminished. Thus production in 1944 in California was 21,540 tons, in 1945, 1,668 tons, and in 1946, though exact figures are not yet available, it was at most only a few hundred tons.

Natural Gas

Solano County is the most important producer of dry gas and has the greatest amount of new drilling activity. New producing wells recently have been drilled in three different areas in this county and in the Thornton area of Sacramento County. In the Rio Vista field of Solano County, a total of 132 wells were connected to pipe lines at the beginning of 1947. Farther to the north three new dry gas areas have been developed. One is a new discovery in the Winters area; the second is in the Dunnigan Hills area, Yolo County, 12 miles northwest of Woodland; and the third is in the Durham area of Butte County 5 miles south of Chico.

The Trico gas field is in the extreme southwest corner of Tulare County near the southeast corner of Kings County and extends a short distance into Kern County. Recent drilling has developed an extension of this field to the northwest to almost double the proved acreage available for production. A new gas zone has been discovered 800 feet deeper than the old one, and this new zone is expected to produce as much gas as the old one, thus adding greatly to the reserves of this field.

Natural gas is a mineral of high value in California with an annual production several times as valuable as the present (1947) production of gold. Gas is produced from two types of fields. In one type the gas is produced as a by-product of oil production; and in the other type, known as dry gas fields, no oil accompanies the gas.

Special study No. S-584 of the State Department of Natural Resources and the California Public Utilities Commission, released in May 1947, indicates that a number of areas in California would be inadequately served with gas on a day as cold as the coldest day on record in the last 20 years. Included in these areas are the peninsula district on San Francisco Bay and the metropolitan district of Los Angeles.

A pipe line 30 inches in diameter is being constructed from Texas to California and is expected to be completed by the end of 1947. Other pipe-line facilities that will help to increase supplies of natural gas include a line from the Kettleman Hills to a point near Pittsburg, which has been restored to gas service after having been leased for delivery of oil since 1942. This line is primarily 26-inch, but contains some 22-inch pipe. A new line has recently been built from the Rio Vista and nearby fields not previously drawn upon. It contains 36 miles of pipe ranging in diameter from 4 to 12 inches. A number of other new lines have been built in the Livermore, Chico, and Trico areas.

Petroleum

New discoveries of petroleum are continually being made in California, but not at a rate fast enough to keep up with demands. Hence, California is now importing some petroleum. Recent discoveries in the Coast area include a deep zone in the Casmalia field, but only one well is productive, although others were drilled on the structure. In the Elwood field eight new wells have developed production westward into the tidelands. The West Mountain area in Ventura County now contains five producing wells. Although a number of wells have been drilled previously, this is the first commercial production.

In the Los Angeles Basin two important discoveries have been made recently: one the East Los Angeles field east of the city of Los Angeles; and the other the Alondra Park area in the western part of the Los Angeles Basin. Wells in these areas are 8,000 to 10,000 feet deep, and the fields are still being developed. The discovery at Alondra Park was made in 1946, but a second well has been completed in 1947. A new discovery has been made in the Hyperion area, and extensions of existing fields have recently been found at Aliso Canyon and Dominguez fields. In Orange County two large wells have recently been completed in the midst of old producers: one in the East Coyote field, which is the first flowing well to be completed in many years; the other in the Brea-Olinda field.

An experimental water-flooding project at Richfield oil field has resulted in the recovery of oil attributed to the flooding operation.

In Ventura County, on the Oxnard Plain, near Montalvo, a discovery has been made in 1947 of light-gravity oil that contains a high percentage of gasoline. This appears to be an important discovery and is being further developed. The State Lands Commission is advertising for bids for oil leases on 1920 acres at the mouth of the Santa Clara River.

The value of petroleum produced in California each year for many years has been greater than the total value of all other mineral products produced in the state during the same year. Almost as much petroleum is being produced in 1947 as during the peak year of the war. Production is amounting to 910,000 barrels per day in May 1947, or 50,000 more barrels per day than a year ago. Production this year may surpass the all-time high of the year 1945. The increased demand is due to new industrial plants, the influx of population to California causing a high demand for gasoline, and to high demands of the United States Navy.

Platinum

The platinum produced in California comes entirely as a by-product from placer mining for gold. Its original source is thought to be in the abundant ultrabasic rocks of northern California. Principal production has come from dredges operating in Amador, Butte, Merced, Sacramento, Stanislaus, Shasta, and Siskiyou Counties. Most of the dredges were shut down in October 1942 by War Production Board Order L-208, and much of their equipment including draglines, bulldozers, electric motors, rubber belts, pumps, generators, welding equipment, and other machines and parts were sent to the war industries. Since the restrictions were removed in July 1945, many of the dredges have been able to get needed equipment and to resume operations. Others are being assembled and will get into operation during 1947. Some are still idle because they have not been able to get draglines; others are waiting for costs of labor and supplies to go lower or the price of gold to be raised.

Some platinum is probably lost because many operators feel that the effort necessary to recover it is unprofitable. Before the war a few firms made a business of collecting the black sands from the dredges and recovered the platinum metals in their plants on a percentage basis. This practice may be resumed as additional dredges get into operation, and production of the platinum metals may be increased.

Potash

The American Potash & Chemical Corporation is the only producer of potash in California. Production of the company's plant at Trona, San

Bernardino County, where it is extracted from the brines of Searles Lake, has been steadily increasing from 1927, when it amounted to 67,300 tons, to an annual production of approximately 190,000 tons in 1944.

Over 90 percent of the potash consumed in the United States is for agricultural use, the remainder being used in the chemical and industrial fields. Demand for potash for agricultural purposes should increase in 1947.

Pumice and Perlite

The natural reserves of volcanic glasses in California are unlimited. Pumice is a highly vesicular volcanic glass formed during explosive volcanic eruptions. It is the result of expansion of water vapor and other gases within an acid magma when pressure is suddenly relieved at elevated temperature. Perlite is one of the family of acid volcanic glasses (obsidian) characterized by an appreciable content of dissolved or chemically combined water and gases. If perlite is heated suddenly to a temperature range between 1400 and 2200 degrees Fahrenheit under controlled conditions, an expansion of the gases within the plastic mass of semimolten glass takes place, and the resulting product is similar to pumice. Both expanded perlite and pumice can be described as glass foam, thin-walled glass bubbles enclosing a partial vacuum or air space.

Pumice has for many years been used as an aggregate or filler, as an abrasive, and in many other ways. In recent years its principal use has been as a light-weight aggregate or filler in concrete, plaster, and with binders to form light, fairly strong building units and materials with excellent insulating properties against heat, cold, and sound. The demand for such light-weight aggregate is increasing greatly, and accounts for over 95 percent of the California production at present. Expanded perlite can be substituted for pumice in all of its uses and in many applications with better technical and economic results.

Pumice deposits are widely scattered in the western states and are usually relatively small in size and variable in physical characteristics. Perlite deposits are usually found in the same general localities as pumice deposits and are in general much larger in tonnage and more concentrated in area than pumice deposits.

Most pumice and perlite deposits are relatively distant from large consuming centers. Marketing pumice involves shipping for long distances a friable, bulky, light-weight material of variable moisture content. Perlite may be shipped as a crude, heavy run-of-quarry rock at low freight schedules, into consuming centers and there expanded, usually with appreciable saving in cost of transportation compared with pumice.

Pumice, produced by natural forces, is a glassy froth, variable in physical as well as chemical properties. Perlite is variable in its chemical properties in the raw state, but the expansion is controlled by man instead of by a volcano; hence the physical properties of the expanded perlite (synthetic pumice) are controlled within narrow limits, and a uniform product conforming to definite specifications can be made even though the raw material may be somewhat variable in composition.

In 1943, a little over 21,000 tons of pumice were produced in California. In 1946, nearly 110,000 tons valued at over $500,000 were produced. Indications are that the demand is increasing at an accelerated rate in 1947.

Expanded perlite is just beginning to be a factor in the light-weight filler and aggregate industries, and in other applications. The signifi-

cance of the fact that perlitic obsidian will expand upon proper heating was realized only a few years ago, and the technical problems in processing perlite have only recently been solved. Production of processed perlite in 1946 was on the order of a few hundred tons in California, but future growth of the perlite industry will probably be very rapid, and total sales volume may exceed sales of pumice within a few years, as new materials and techniques are applied to building construction.

Pyrites

Large deposits of massive and disseminated pyrite occur in California. The Mountain Copper Company in Shasta County has been the only California producer recently. At their Hornet mine in Shasta County pyrite occurs in massive deposits affording cheap mining. It is reported to average about 50 percent sulphur and is shipped to manufacturers of sulphuric acid located near San Francisco Bay.

Pyrites is the name given the iron sulphide minerals such as pyrite, marcasite, and pyrrhotite. Pyrite and marcasite have the same chemical composition and when pure contain about 47 percent iron and 53 percent sulphur. Their chief use is in the manufacture of sulfuric acid, which is being used in increasing amounts on the west coast in the fertilizer, oil refining, and chemical industries. Operations in Alameda County formerly yielded large tonnages, but these have not been active for many years.

Quicksilver

The state of California has the largest production of quicksilver of the United States, with an output of about 70 percent of the total. Falling prices are gradually causing the industry to decline. During the war about 100 properties were producing, but this has been reduced to about 30, of which only 6 are now making an output of more than 300 flasks of 76 pounds each per year. The New Idria mine, San Benito County, is the largest producer.

The chief use of mercury is in the manufacture of chemicals and pharmaceuticals such as calomel and various antiseptics. In the past an important use has been in the fulminate, a high-explosive compound used in percussion caps and detonators. Substitutes for this use have been developed that are safer and more reliable, which are now preferred to mercury fulminate. As quicksilver, or mercury, is the only metal that is liquid at ordinary temperatures, it is very useful in many industrial and control instruments, such as gas-pressure gauges, tank gauges, gas-analysis apparatus, flow meters, heat-control devices, thermometers, and barometers. In the electrical industry, it is used in mercury-vapor lamps, fluorescent lamps, rectifiers, oscillators, and switches. A use that attracted considerable attention toward the end of the war was in a new type of dry-cell battery. Peace-time uses of this battery are expected to develop still further for such things as small radios and hearing-aids.

Spanish and Italian producers control the world market for mercury through a cartel. United States tariff of $19.00 per flask is inadequate to afford much protection from this combination, because European producers are able to pay this tariff and still undersell domestic producers by a large amount. At present costs of labor and materials, a price of $125.00 per flask is needed to keep California's quicksilver industry in a healthy condition, with proper exploration and development

4—76940

of ore reserves. In mid-1947 quicksilver was quoted at $84.00 to $87.00 per 76-pound flask; hence, further curtailment of production must be expected.

Salt

Plants producing salt from sea water are operated on San Francisco, Monterey, and San Diego bays, and at Long Beach. Inland regions producing salt are Imperial, Kern, and San Bernardino Counties.

The production of salt is a thriving industry in California, amounting to considerably more than $2,000,000 per year. Production has more than doubled in the past 10 years; in 1937 it was only slightly over $1,000,000. Most of the salt is derived from the evaporation of sea water, but some comes from desert lakes and some is mined from deposits of rock salt.

Besides the common use of salt on the dinner table and for feeding stock, this saline mineral has many uses, most important of which is in making soda ash. Salt is the original raw material for nearly all chemical compounds of sodium and chlorine; one manufacturer has listed 1400 uses. Most of the soda ash produced in the world is derived from salt, but in California natural sources of soda ash are available.

Silica

California has large potential reserves of quartz, but most of these deposits are so situated that exploitation is economically impractical at present prices of $2.50 to $5.00 per ton f.o.b. plant for crude crushed quartz. Large and accessible deposits of high-grade glass sand are not known in California, but large reserves of lower-grade sands, suitable for glass making after processing, are known. Further expansion of the glass industry in the state will result in the exploitation of these deposits, with consequent emphasis on research into economical methods of removing the impurities present either by washing, tabling, magnetic separation, flotation, or combinations of these and other processes.

Reserves of siliceous rock and sand suitable for refractory use in ganister and silica brick, and for use as molding sand are abundant in California, and the production of these materials is a rapidly growing industry. However, no open price schedule exists for glass sand, ganister rock, quartz, or molding sand, as production of these materials is made largely from owned or leased deposits by users of these materials, and prices are those fixed for the convenience of bookkeeping.

Silica is the principal constituent of many natural sands but in this paper the special uses of silica in glass, ceramics, chemicals, refractories, and as a filler are here considered separately from the common sand used in concrete and plaster. Such special uses have increased greatly in the past few years. Quartz and glass-sand production has increased from 70,835 tons valued at $297,272 in 1935 to 592,239 tons worth $1,404,242 in 1946. Most of this large increase is the result of the expansion of the glass industry in California in recent years, and present indications are that the demand for glass sand and quartz is increasing.

Sillimanite (Andalusite, Kyanite, and Dumortierite)

Production of andalusite and kyanite previous to 1945 was approximately 2000 tons per year. In 1945, Champion Spark Plug Company

ceased work at its andalusite deposit in Dry Creek Canyon in the White Mountains, Mono County, and all equipment has been sold. The Vitrefrax Corporation of Los Angeles, owner and operator of a kyanite deposit near Ogilby, Imperial County, also suspended operations and liquidated its plant in Los Angeles. The outlook for any production of andalusite or kyanite is not favorable for 1947.

Silver

Few mines in California have been operated primarily for the production of silver, but this metal is recovered as a by-product of gold mining, of zinc-lead mining, and of copper mining. In 1940 the principal producer of silver was the Cactus Queen mine in Kern County, a gold-silver mine, and the second largest producer was the Lava Cap mine in Nevada County, a gold mine. Recently the largest silver producer has been the Darwin group in Inyo County, a zinc-lead mine operated by Anaconda Copper Mining Company.

Soda Ash

Soda ash is one of the most important of the alkalies and is produced in greater quantity than other heavy chemicals except sulfuric acid and common salt. The source of California's soda ash is at present natural brines. Soda ash may be produced from common salt by various methods involving large capital investment in plant and from natural deposits of the carbonates of sodium found in saline lakes and in bedded deposits. In the United States, about 90 percent of the soda ash marketed is produced from common salt, principally in the eastern and midwestern states.

A recent survey indicates that the United States demand for soda ash will exceed the supply by an appreciable margin at least for several years without allowance for exports, for which great pressure exists, because of the general world shortage of soda ash. This condition is accentuated in California because of the rapid growth of industry and population. Of the total demand for soda ash, the glass, soap, and cleanser industries require about 37 percent, the chemical industry about 49 percent, the pulp and paper, aluminum, textile, and petroleum industries combined about 11 percent, and miscellaneous industries about 3 percent. The California glass, soap, and chemical industries, now being expanded, are all in the category of heavy users of soda ash, and the demand for this chemical will increase in California at a greater rate than in the United States as a whole. This will entail further expansion of existing plants extracting soda ash from California brines and lake beds, development of potential natural reserves such as the brine of Mono and other saline lakes in the southern part of the state, and possibly the installation of one or more Solvay process plants on the Pacific Coast for the conversion of salt to soda ash. As this type of plant requires a very large capital investment (on the order of $30,000 per ton capacity per 24 hours) and is economical only in large units (500 to 1000 tons per day), probably intensive development of California reserves of natural soda ash will take place in the order of their potential economic value before the building of plants for the conversion of salt. The future production of the Green River, Wyoming, deposits will doubtless supply part of the California demand, but the pressure of midwestern and eastern demand, as well as

Washington and Oregon potential demand and exports, will probably absorb a very appreciable part of the Green River production.

Stone, Miscellaneous

Stone for road surfacing and concrete aggregate has been produced in every county in California; such material has a wide variety of other uses. Great irregular chunks of 10 tons each, known as riprap, are dumped from barges into shallow parts of bays to form the sea-walls behind which sand and mud are pumped to reclaim the land; but in some of the metropolitan districts satisfactory and abundant riprap cannot be found near at hand. Small sizes of rock are used for railroad ballast, and the accompanying finely divided material is used in concrete and plasters. Certain types of sand are mined especially for making molds in foundries.

Many different types of stone are used; also there are many ways of producing them. The 10-ton chunks of riprap are blasted from solid bodies of basalt and granite. One of the largest granite quarries is located near the San Andreas fault, where the faulting has crushed the granite to the extent that the amount of explosives needed is much lower than average. In Butte and Sacramento Counties, crushed rock is produced from old dredge-tailing; thus the waste from the gold-dredging industry becomes the valuable raw material of the crushed-rock industry. A favorite method of producing sand and gravel is to excavate the bars along streams with various types of dragline excavators. The pits thus formed are sometimes re-filled by winter floods. Nature has had a part in improving the quality of this material; soft decomposed rocks have been pounded and pulverized and washed away as mud; the harder, more resistant rocks remain. In some plants the sand and gravel are washed and separated into various sizes by screens only; but most plants contain crushers to reduce the size of the cobbles and boulders.

Concrete highways, dams, aqueducts, and canals require great quantities of sand, gravel, and crushed rock for aggregate. As long as this type of construction continues at a high level, the stone industry will continue to flourish. Smaller quantities of such material go into foundations, walls, and floors of buildings.

Limestone is higher in value in most California deposits than other stones for various industrial and chemical uses, but in a few places it is quarried for surfacing roads.

Strontium

Strontium occurs as the sulphate, celestite, and the carbonate, strontianite. Large undeveloped deposits of celestite occur as ancient lake deposits in San Bernardino, Imperial, and Inyo Counties. The production has been from Imperial and San Bernardino Counties. Properties recently operated are the Roberts deposit in Fish Mountains, Imperial County, and Rowe-Buehler deposit near Lavic, San Bernardino County.

The present output is less than 1000 tons per year, and owing to imports from England, any increase in production for 1947 is not probable. Possibly celestite will be used as a substitute for barite for oil-well drilling mud.

Sulfur

Deposits of native sulfur are known to occur in Alpine, Colusa, Imperial, Inyo, Kern, Lake, Sonoma, Tehama, and Ventura Counties. Production has been erratic, but in some recent years has amounted to nearly 10,000 tons per year, chiefly from Inyo County. The Leviathan mine, a well known deposit in Alpine County, was acquired in 1945 by Siskon Mining Corporation, which is now proceeding with development and experimental work.

Talc, Steatite, and Pyrophyllite

Practically all the production of talc and steatite comes from Inyo and San Bernardino Counties. Soapstone was produced recently in minor amounts from deposits in Amador and El Dorado Counties.

Pyrophyllite occurs in four localities, and some increase in production was noted in 1946. Two deposits occur in White Mountains, north of Bishop in Mono County, one near Victorville, San Bernardino County, and one near Rancho Santa Fe, San Diego County. Pyrophyllite mined from the San Diego County deposit is hauled to Chula Vista for grinding and is shipped as a dust product to the Mefford Chemical Company of Los Angeles. The absorbent quality of pyrophyllite recently has led to its widespread use as a carrier for chemicals in insecticides.

The principal production of steatite is from Inyo County. Production of talc has increased steadily since 1940, and the 1946 production was valued at nearly $1,000,000, the highest on record for California. The outlook for increased production in 1947 appears to be very favorable as operators are predicting further increase in the output. The average value reported by producers in 1946 was $13.29 per ton for crude talc at mines. Ground talc is reported to sell for $20.00 to $40.00 per ton delivered to consumer. Producers are Pacific Minerals Company, El Dorado County; Blue Star Mines, Ltd., Kingston Mountain; Death Valley Talc Company, Furnace Creek; Sierra Talc Company, Keeler; J. E. Lane & Fred Nikolous, Big Pine; and White Mountain Talc, Lone Pine, in Inyo County; Monarch Talc Mines, Shoshone; Sierra Talc Company, Silver Lake; Southern California Minerals Company; Kingston Mountain; Western Talc Company, Shoshone, San Bernardino County.

Tungsten

There are hundreds of deposits of scheelite in California and some of them represent the largest known low-grade reserves of tungsten in the United States.

The largest producer in California, the U. S. Vanadium Corporation, is expected to resume milling operations at its Pine Creek mine in Inyo County in July of this year. Recently their activities have been confined to underground development. The capacity of this plant is 1400 tons of ore per day.

The Tungstar mine on Mount Tom, west of Pine Creek, about 3½ miles southeast of the Pine Creek mine, is doing development work preparatory to reopening of its mill. El Diablo Mining Company is developing a deposit on Pine Creek above the mill of U. S. Vanadium Corporation and although hampered by snow may be expected to resume

operation of its mill in the next few months. Hoeffling Bros. are producing from placers east of the Union mine at Atolia, recovering both gold and tungsten.

Although the price of tungsten concentrates is from $28.00 to $30.00 per unit little production is resulting in the state at this time (June 1947). The above price apparently is a foreign market price; Great Britain and Russia entered the market the first of the year, and more recently France has started buying. This means that the domestic price is nearer $26.00 per unit, there being a $4.00 differential. Action yet to be taken on foreign trade agreements may have a bearing on these prices.

Even though the production of tungsten in California is now very small the outlook is not gloomy. The larger producers are preparing to resume operations and the present price is sufficient to attract other operators to this field.

Zinc

California zinc minerals are closely associated with copper in Shasta and Calaveras Counties, and with lead deposits in Inyo County. Zinc has been produced recently in Amador, Butte, Mariposa, Orange, San Bernardino, and Siskiyou Counties also. Zinc and copper minerals are so intimately associated in Shasta County ores that deposits containing 16 percent zinc, 2 percent copper, and 5 ounces of silver per ton were left as unprofitable to mine about 25 years ago. Premiums paid for zinc and associated metals, and particularly advances in the technique of selective flotation, make it profitable to mine these ores, and zinc production has been over a million pounds each year since 1942. The present high cost of mining, and the uncertainty that premium payments will be continued beyond June 30, have discouraged development, and most deposits have been mined without development of reserves.

Geologic knowledge concerning the character of the Shasta County deposits and their structural control, together with their geophysical characteristics, promise to disclose zones where zinc ore bodies may be confidently sought by core drilling. Shasta County properties are being developed as probable producers of both zinc and copper.

Zinc ores now mined in California must be sent to Utah and Montana for smelting and refining. Production of zinc reached a high of 19,340,732 pounds in 1945, declined to 14,639,804 pounds in 1946, and is declining further in 1947.

MINES AND MINERAL RESOURCES OF SISKIYOU COUNTY

By J. C. O'Brien*

OUTLINE OF REPORT

ILLUSTRATIONS

INTRODUCTION

Geography

Siskiyou County is one of the three northermost counties of California. It borders on the state of Oregon for some 110 miles and is bounded on the west by Del Norte and Humboldt Counties, on the east by Modoc County, and on the south by Shasta and Trinity Counties. It is from 60 to 70 miles wide and has an area of 4,040,320 acres, of which about 68 percent is in the public domain. The Klamath National Forest

* District Mining Engineer, California State Division of Mines. Manuscript submitted for publication June 30, 1947.

alone has an area of 1,291,619 acres; Shasta National Forest, 712,168 acres; and Modoc National Forest 92,419 acres, within the county.

Siskiyou County had a population of 28,598 according to the 1940 census. Yreka, the county seat, is located on U. S. Highway 99 about the center of the county. A branch line about 7 miles long connects it with the mainline of the Southern Pacific Railway at Montague.

Topography

The region is mountainous throughout the western half of its area but several valleys in the central and east-central sections include about one-fifth of the total area, and farming ranks second to lumbering as a basic industry. The Klamath Mountains cover approximately the western half of the county and include the Siskiyou, Salmon, Marble, and Scott Bar ranges. These are among the wildest and most rugged in California. Prominent peaks and ridges rise 6000 to 8000 feet above sea level. The drainage is transverse and irregular, having developed on an uplifted plateau. The Klamath River flows west and south through deep, rocky canyons, and has left many gold-bearing gravel benches, terraces, and bars along its course. Its principal tributaries, the Shasta, Scott, and Salmon Rivers, flow in a generally northwesterly direction and each in turn has numerous forks and tributaries which have been mined for their gold-bearing gravels.

The Cascade Range is wholly of volcanic origin and includes a chain of cones in the central and east-central portion of the county. Mount Shasta, the most prominent cone, elevation 14,162 feet, is the second highest mountain in the state. Glass Mountain on the western border of the Cascade Range is a huge mass of black obsidian and glass flows, and has many square miles of pumice and volcanic cinder beds along its edges.

The eastern boundary of the county includes a portion of the Modoc Plateau, elevation 4000 to 6000 feet above sea level. It is an area covered by thick lava and tuff beds that have issued from numerous small volcanic cones and vents and is the southern extension of the volcanic plateau that covers eastern Oregon and southeastern Washington.

The low valley areas have warm summers and mild winters with little snowfall. The mountain areas are cool, and some of the high peaks are snow covered until late summer. The annual precipitation averages 50 inches or more in the extreme western areas and decreases to about 10 inches in the northeastern corner of the county.

Transportation

The main line of the Southern Pacific Railway crosses the central part of Siskiyou County from north to south, and there are a few short feeder lines to the east. U. S. Highway 99 follows along the railroad for most of its length across the county. U. S. Highway 97 leaves Highway 99 at Weed and runs northeastward through the county to Klamath Falls. State Highway 96 leaves U. S. Highway 99 where it crosses the Klamath River about 9 miles north of Yreka, follows the river westward and southward to Somes Bar and joins U. S. Highway 299 at Willow Creek in Humboldt County. The U. S. Forest Service has built roads along the principal rivers and forks, making it possible to drive an automobile or truck to many areas reached only by trail a few years ago. Many primitive areas are still left in the county, where scarcely a trail exists.

Geology

The eastern half of Siskiyou County is included in the Cascade Range and Modoc Plateau geomorphic provinces. The Geologic Map of California (Jenkins, O. P. 38) shows it to be covered with Tertiary and Quaternary volcanics, Pleistocene lake beds and Recent alluvium. Building stone, crushed rock, and pumice are mined in this area.

The western half of the county is within the Klamath Mountains province and the geologic formations and mineral deposits are similar to those found in the Sierra Nevada province. Its geologic history is described by J. S. Diller (14, pp. 13-14) as follows:

"Little is known of the early geologic history of the Klamath Mountain region, yet it is evident that in pre-Devonian [Diller, J. S. 03, p. 343], possibly in Algonkian [Hershey, O. H. 01, p. 245] or late Archean [Hershey, O. H. 12, p. 273] time the region was beneath the ocean, receiving the sediments from which the mica schist and intercalated crystalline limestones of South Fork Mountain and the Salmon Mountains north of Weaverville were formed.

"The extensive development of Devonian and Carboniferous shales, sandstones, cherts, and limestones in the Klamath Mountain region shows that at least a part of the region continued beneath the sea through the whole or the greater part of the Paleozoic era, but the incompleteness of the succession and the discordance among the formations bear evidence of considerable earth movements at several times during the long period of sedimentation, culminating in the great mountain-building epoch at the close of the Jurassic. At times, too, while these sedimentary rocks were forming, especially before the Middle Devonian and during the later part of the Carboniferous and the greater portion of the Mesozoic, volcanoes were active in the region, giving rise to extensive sheets of contemporaneous lava and tuff intermingled with the sedimentary rocks and in many places covering them.

"About the close of the Jurassic period this complex of sedimentary and igneous rocks was compressed, folded, faulted and uplifted to form the Klamath Mountains, and at the culmination of this process the mass was intruded by coarse granular bodies of plutonic rocks, such as granodiorite, gabbro, and peridotite, and by many dikes having a wide range in chemical and mineral composition.

"As a consequence of this intense, varied, and long-continued igneous action, the heated circulating waters finally formed many ore deposits within the intruded masses or near their contacts. These deposits may have been enriched later by descending waters from the zone of oxidation.

"Erosion and subsidence during the Cretaceous period reduced the Klamath Mountains to sea level, and for a brief interval they may have been completely covered by the ocean, for remnants of a once continuous sheet of conglomerates, sandstone, and shale are widely distributed in the region.

"At the close of Cretaceous time the Klamath Mountains were again uplifted, and with a number of later oscillations and the consequent erosion they have been carved to their present form by streams, which have concentrated the gold in the auriferous gravels."

MINES AND MINERAL RESOURCES

Production Statistics

The mines of Siskiyou County between 1880 and 1945 yielded mineral products valued at $50,830,383. Several million dollars worth of gold were probably mined before 1880, when mineral statistics were first recorded. Although gold has been by far the principal mineral produced, some 16 other mineral products including asbestos, chromite, coal, copper, gem stones, lead, limestone, manganese, marble, mineral water, platinum, pumice, quicksilver, sandstone, silver, and miscellaneous stone, have contributed to the total. The mines and mineral deposits that have shown some activity since the last Siskiyou County report of the Division of Mines (Averill, C. V. 35) are described in the following pages. A few that have been idle are included because of their past prominence.

Mineral production of

Year	Gold, value	Silver, value	Chromite		Mineral water	
			Tons	Value	Gallons	Value
1880	$440,735	$95,340	----	----	----	----
1881	850,000	1,500	----	----	----	----
1882	720,000	----	----	----	----	----
1883	400,000	----	----	----	----	----
1884	475,000	----	----	----	----	----
1885	338,659	----	----	----	----	----
1886	342,677	64	----	----	----	----
1887	606,859	177	----	----	----	----
1888	625,000	----	----	----	----	----
1889	915,294	370	----	----	----	----
1890	860,303	23	----	----	----	----
1891	957,220	120	----	----	----	----
1892	1,013,332	56	----	----	----	----
1893	799,108	----	----	----	----	----
1894	760,782	----	----	----	----	----
1895	950,006	177	----	----	200,000	$80,800
1896	1,091,265	653	----	----	[3]	----
1897	842,123	34	----	----	[3]	----
1898	768,804	321	----	----	[3]	----
1899	991,771	100	----	----	[3]	----
1900	951,397	[2]6,700	----	----	700,000	45,000
1901	886,043	[2]2,980	----	----	700,000	175,000
1902	906,989	233	----	----	750,000	187,500
1903	613,576	22	----	----	750,000	50,000
1904	892,685	1,230	----	----	750,000	50,000
1905	803,035	2,499	----	----	[3]	----
1906	[3]	[3]	----	----	[3]	----
1907	398,017	3,037	----	----	725,000	36,250
1908	504,156	6,125	----	----	700,000	80,000
1909	416,160	2,145	----	----	500,000	10,000
1910	437,376	2,322	----	----	500,000	60,000
1911	422,297	2,561	----	----	700,000	120,000
1912	472,314	2,980	220	$2,310	700,000	120,000
1913	[4]180,125	[4]1,228	----	----	700,000	120,000
1914	312,842	1,026	----	----	650,000	65,000
1915	426,716	2,081	[3]	----	626,680	62,990
1916	441,307	2,312	2,251	28,731	502,650	50,530
1917	325,550	16,883	2,046	49,797	503,000	50,600
1918	294,227	14,501	6,612	336,588	501,750	50,175
1919	226,525	17,049	510	13,379	451,500	90,375
1920	80,707	5,218	215	5,732	300,150	60,015
1921	42,635	294	[3]	----	250,150	5,015
1922	75,105	612	----	----	----	----
1923	45,633	298	----	----	200,150	4,042
1924	63,570	296	----	----	----	6,100
1925	180,120	831	----	----	[3]	----
1926	141,240	709	----	----	[3]	----

Siskiyou County, 1880-1945

Platinum-group metals		Miscellaneous stone[1], value	Miscellaneous and unapportioned		
Ounces	Value		Amount	Value	Substance
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
100	$600	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	------------	
------------	------------	------------	------------	$1,202,742	Unapportioned, 1900-09.
------------	------------	------------	------------	------------	
------------	------------	------------	200 lbs.	23	Copper.
------------	------------	------------	------------	------------	
1.6	21	------------	------------	------------	
5.3	93	------------	2,500 cu. ft.	1,250	Sandstone.
------------	------------	------------	2,500 cu. ft.	1,500	Sandstone.
			193 lbs.	39	Copper.
			2,643 lbs.	140	Lead.
------------	------------	$39,000	11,433 cu. ft.	12,897	Sandstone.
			1,000 bbls.	1,000	Lime.
			2 20 tons	300	Limestone.
			4,949 lbs.	1,183	Lead.
------------	------------	------------	1,800 cu. ft.	1,485	Sandstone.
			1,090 lbs.	1,680	Lime.
			3,360 lbs.	144	Lead.
			50 tons	500	Pumice.
------------	------------	5,028	1,050 cu. ft.	1,750	Sandstone.
			100 bbls.	300	Lime.
			2,225 tons	2,200	Limestone.
			------------	14,745	Gems.
------------	------------	9,475	1,204 cu. ft.	2,000	Sandstone.
			335 bbls.	735	Lime.
			35 tons	525	Limestone.
			------------	1,000	Gems.
------------	------------	6,580	150 bbls.	120	Lime.
			24 tons	24	Limestone.
			650 cu. ft.	455	Sandstone.
			250 cu. ft.	250	Sandstone.
------------	------------	609	------------	250	Gems.
			------------	250	Gems.
------------	------------	4,883	90 tons	2,000	Pumice.
			------------	1,500	Other minerals.
			100 tons	500	Coal.
9	304	5,371	58 lbs.	2	Lead.
			677 bbls.	629	Lime.
			250 cu. ft.	150	Sandstone.
			188 lbs.	9	Lead.
------------	------------	4,630	745 bbls.	745	Lime.
			------------	16,923	Chromite, copper, marble, sandstone.
[3]	------------	45,407	------------	12,609	Copper, building stone, lime, platinum, sandstone.
			------------	500	Granite.
15	709	134,382	888,043 lbs.	242,436	Copper.
			192 lbs.	17	Lead.
			------------	8,535	Lime, sandstone, soda.
1	58	24,588	573,593 lbs.	141,677	Copper.
			------------	15,473	Lead and pumice.
7	1,015	26,405	------------	111,294	Copper, limestone, pumice, quicksilver.
------------	------------	30,322	------------	47,121	Copper, lime, limestone, potash, pumice, quicksilver.
[3]	------------	44,343	------------	1,060	Asbestos, brick, chromite, lime, platinum.
------------	------------	21,726	------------	4,020	Other minerals.[5]
3	339	129,291	------------	1,408	Other minerals.[6]
------------	------------	67,787	------------	3,034	Other minerals.[7]
[3]	------------	23,800	------------	3,535	Lime and limestone.
			------------	11,340	Mineral water, platinum, sandstone.
16	1,780	327,569	------------	22,853	Coal, lead, mineral water, sandstone.

Mineral production of

Year	Gold, value	Silver, value	Chromite		Mineral water	
			Tons	Value	Gallons	Value
1927	$138,822	$586			[3]	
1928	85,717	421			[3]	
1929	63,843	863			[3]	
1930	70,332	4,172			[3]	
1931	74,326	169			[3]	
1932	133,115	304			[3]	
1933	324,954	686			[3]	
1934	528,395	1,861			[3]	
1935	575,676	1,610			[3]	
1936	639,030	2,873				
1937	1,055,600	3,420			[3]	
1938	1,294,230	3,335			[3]	
1939	1,708,840	5,196	[3]		[3]	
1940	2,068,815	6,651			[3]	
1941	2,351,790	7,135	[3]		[3]	
1942	1,356,530	4,187	[3]		[3]	
1943	110,040	6,712	[3]		[3]	
1944	128,870	10,203	2,225	$89,650	[3]	
1945	93,345	1,799	[3]		[3]	
Totals	$38,091,555	$257,290	14,079	$526,187	[3]12,361,030	$1,579,392

Grand total value, $50,830,383.

[1] Includes crushed rock, rubble, rip-rap, sand, gravel.
[2] Recalculated to 'commercial,' from 'coining value' as originally published.
[3] See under 'Unapportioned.'
[4] Production from dredging operations included in Stanislaus County production.
[5] Includes limestone and mineral water.
[6] Includes lead and lime.
[7] Includes coal, limestone, lime and platinum.

Asbestos

The industries of World War II created a great demand for all types of asbestos, and during the war prospectors were urged to search for deposits in the serpentine areas of Siskiyou County. No new deposits were discovered, however, and there was no production from the previously known prospects and occurrences.

Chamberlain (Burns) Ranch includes 800 acres of patented land about 4 miles west of Gazelle in secs. 16, 17, 20, T. 42 N., R. 6 W., owned by C. C. Chamberlain. A light-green, brittle, chrysotile asbestos occurs in dark-green serpentine bands up to three-eighths of an inch wide. It has been exposed in a trench 5 feet wide, 20 feet long, and 3 feet deep. The mineral rights to this property are under lease to Ray J. Sylvester of Weed. (Logan 25, p. 421; Averill 35, p. 264.)

C. C. Cady prospect on Greenhorn Mountain, between Yreka and Fort Jones has not been developed since 1935. (Logan 25, p. 421; Averill 35, p. 264.)

Siskiyou County, 1880-1945—continued

Platinum-group metals		Miscellaneous stone[1], value	Miscellaneous and unapportioned		
Ounces	Value		Amount	Value	Substance
10	$690	$102,428	------------	$56,420	Mineral water, sandstone.
------------	------------	370,833	------------	14,195	Copper, lead, gems (rhodonite), mineral water.
------------	------------	110,878	------------	54,205	Copper, lead, limestone, quicksilver, mineral water.
------------	------------	85,851	------------	75,046	Copper, lead, granite, mineral water, gems, platinum quicksilver, lime, pumice.
------------	------------	79,772	------------	32,740	Other minerals.
------------	------------	23,415	------------	27,185	Lead, quicksilver, mineral water.
------------	------------	29,036	------------	19,502	Copper, lead, mineral water, pumice.
------------	------------	67,216	------------	50,694	Copper, lead, mineral water, pumice, tube-mill pebbles.
[3]	------------	66,664	------------	61,787	Copper, mineral water, pumice, tube-mill pebbles.
------------	------------	106,182	1,805 lbs.	166	Copper.
			6,088 tons	49,200	Pumice.
			------------	33,652	Lead, mineral water, platinum, tube-mill pebbles.
------------	------------	103,519	1,168 lbs.	144	Copper.
			------------	37,668	Lead, gems, mineral water, pumice, quicksilver, tube-mill pebbles.
[3]	------------	116,331	------------	96,919	Copper, lead, mineral water, platinum, pumice, tube-mill pebbles.
[3]	------------	99,906	701 tons	5,169	Pumice.
			------------	30,884	Chromite, mineral water, platinum, tube-mill pebbles.
[3]	------------	102,923	637 tons	2,250	Pumice and scoria.
			------------	38,564	Copper, mineral water, platinum.
[3]	------------	141,439	7,132 tons	16,330	Pumice.
			------------	61,531	Chromite, copper, lead, mineral water, platinum, quicksilver.
[3]	------------	105,952	7,668 lbs.	928	Copper.
			------------	152,917	Chromite, gems, lead, mineral water, pumice, quicksilver, platinum.
------------	------------	221,837	9,707,958 lbs.	1,262,035	Copper.
			------------	295,622	Chromite, manganese ore, mineral water, quicksilver.
------------	------------	96,369	15,856,568 lbs.	2,140,637	Copper.
			------------	42,195	Manganese ore, mineral water, pumice.
------------	------------	145,327	4,042,886 lbs.	545,787	Copper.
			5,230 tons	36,470	Pumice.
			------------	103,577	Chromite, diatomite, limestone, mineral water.
167.9	$5,609	$3,127,074	------------	$7,243,276	

Shasta View prospect in sec. 8, T. 41 N., R. 5 W., consists of 12 unpatented claims owned by William W. Gassoway and George C. Taylor. They are leased to Ray J. Sylvester of Weed. Mr. W. S. Russell of Edgewood is reported to have produced several tons of fiber from these claims in 1921. Bands of green, brittle, asbestos with fibers up to three-fourths of an inch long occur in zones in peridotite. On the Shasta View claim an adit striking N. 15° W. is caved near the portal. About 50 tons of material on the dump showed fiber one-sixteenth of an inch long in bands spaced from a quarter to three-quarters of an inch apart. The claims have been prospected by several shallow pits and trenches. (Logan 25, p. 421; Averill 35, p. 265.)

Chromite

Chromite mining was resumed in Siskiyou County in 1939 after a lapse of 18 years. Production came from small lenses of high-grade ore found in the peridotite, serpentine, and dunite rocks which outcrop over a large area in the western part of the county.

The Metals Reserve Company established a stockpile at Yreka in the spring of 1942 for the purchase of small lots of chrome and manganese ores. Specifications and price schedules were revised from time to time until May 15, 1943, when ores and concentrates containing a minimum of 35 percent chromic oxide and having a chromium to iron

ratio not less than 1.5 to 1 were accepted in lots of 10 or more long tons. Purchases were continued at the Yreka stockpile until December 31, 1945. This made it possible for many small deposits to be mined by individuals employing from one to ten men. All of the ore was hand sorted and some of the banded and disseminated ores were hand cobbed before shipment. A great deal of the material discarded as too low grade for shipment might have been made into an acceptable concentrate by a gravity milling process.

Barkhouse and Whiskey Boy claims in sec. 11, T. 46 N., R. 11 W., M. D., are owned by A. Lowden of Seiad and leased to K. W. Walters of Happy Camp. About 30 tons of lump chromite were mined from lenses in serpentine on this property in 1943. (O'Brien 43a, p. 328.)

Black Crow and Black Hawk claims (Eldridge) are owned by Virgil Gray and Tom Eldridge of Cecilville, who produced a few tons of chromite from lenses in serpentine in sec. 20, T. 38 N., R. 11 W., M. D. (O'Brien 43a, p. 328.)

Browne Ranch is in sec. 1, T. 41 N., R. 9 W., M. D. Fred P. Browne, owner, shipped 16 tons of chromite from small lenses in serpentine in 1942.

Burton Ranch in sec. 24, T. 44 N., R. 8 W., M. D., is owned by Fred C. Burton of Yreka. Shipments of chromite were made from small lenses in serpentine on this property by J. R. Allison, Clem Baker, Fred W. Burton, William McCoy, Oliver W. Costello, and H. S. Schell and son. Twenty tons of ore, said to have assayed 54 percent Cr_2O_3 with a 2.9 to 1 chromium to iron ratio, were shipped to the Metals Reserve Company stockpile at Yreka in 1945. (O'Brien 43, p. 82.)

Coggins mine in sec. 35, T. 39 N., R. 4 W., M. D., is owned by Arthur L. Coggins of Ashland, Oregon. The U. S. Forest Service built 2 miles of road to this property. Sixteen shallow holes were diamond drilled by the U. S. Bureau of Mines in 1942-43, and an estimated 1000 tons of shipping-grade chromite developed. The property was operated in 1942-43 by James K. Remsen of Grants Pass, Oregon, under a sub-lease from the Rustless Mining Corporation. Massive chromite occurring in lenses in dunite was mined from an adit 212 feet long driven in a N. 17° W. direction. Broken, shifting ground required heavy timbering. Remsen shipped 1,926 tons of chromite worth \$32 to \$33 per ton to the Sacramento stockpile. Ten men were employed on two shifts under Manley Brown, manager.

In 1943, Hugh Williamson of Redding drove a new adit about 40 feet below the old caved workings on this property and shipped an additional 200 tons to the stockpile. (Averill 35, pp. 266, 269; Allen 41, p. 129; O'Brien 43, p. 82; 43a, p. 328; Bradley 18, pp. 191-193.)

Constable and Foster claims are located in sec. 1, T. 41 N., R. 7 W., M. D. Hugh Williamson of Redding mined chromite from a timbered open cut about 70 feet long in a N. 65° E. direction, 4 feet wide and about 18 feet deep, and from an adit driven S. 70° E. for about 30 feet. The chromite had an average width of 2 feet between serpentine walls. The ore was trucked 30 miles to the Yreka stockpile and is said to have averaged 50 percent Cr_2O_3 with a 3 to 1 chromium to iron ratio. (O'Brien 43a, p. 327.)

Costello mine in sec. 24, T. 44 N., R. 8 W., was owned and operated by Oliver W. Costello of Yreka, who shipped 20 tons of lump chromite in 1942.

Cyclone Gap (Mammoth) mine consists of two claims in S½ sec. 15, T. 17 N., R. 5 E., H. The U. S. Forest Service built 22 miles of access road from Waldo, Oregon, to this property in 1942. An irregular body of chromite measuring about 25 feet long, 20 feet thick, and about 60 feet deep occurred in dunite and serpentine. It was mined by open cuts and an adit striking S. 55° E., 110 feet from which raises, stopes, and a winze 26 feet deep were driven to extract the ore. The chromite was hand sorted and trucked 64 miles to the Grants Pass stockpile. James K. Remsen of Grants Pass, Oregon, mined about 2000 tons of 43 to 45 percent Cr_2O_3 from this deposit in 1942. Eight men were employed under Ben Baker, superintendent. (O'Brien 43, p. 82; 43a, p. 328.)

Doe Creek deposit is in W½ sec. 32, T. 17 N., R. 5 E., H. It is owned by Homer White and Jim Hoge of Kerby, Oregon. Two lenses of chromite in serpentine were mined by open cuts. One eastward-trending lens was about 42 feet long, 9 feet wide, and from 15 to 20 feet deep. Another lens, about 100 feet to the northwest, measured about 18 feet in length, 15 feet in width, and 8 feet in depth. In 1942 this property was leased to J. B. Isgrid of Grants Pass, and G. P. Lily of Baker, Oregon. In October 1942 nine men were employed under B. F. O'Frary, superintendent, and about 1500 tons of 38 percent Cr_2O_3 with a 3 to 1 chromium to iron ratio had been produced. The ore was trucked 105 miles to the stockpile at Grants Pass, Oregon.

In August 1944 Linkhart and Messinger of Kerby, Oregon, had a lease on this property. Two men were employed sinking on a lens from which they had mined about 150 tons. (Maxson 33, pp. 139, 153; Allen 41, p. 123; O'Brien 43, p. 82.)

Dry Gulch mine, five claims in sec. 16, T. 38 N., R. 11 W., M. D., is owned by Luther Lake and his wife, and V. A. Gray of Cecilville. About 150 tons of high-grade lump chromite was mined from six small lenses in serpentine at this property in 1944-45.

Fairview Chrome mine, four claims in secs. 27 and 34, T. 46 N., R. 11 W., M. D., was purchased in 1942 by F. S. Pollak of Washington, D. C., from Mrs. Dorothea Reddy Moroney of Yreka. Chromite occurred in parallel bands and disseminated through a tan-colored dunite in a zone about 100 feet wide near the top of a ridge about 3½ miles northwest of Hamburg. It was mined from open cuts and from stopes above an adit driven N. 25° W. following a band of chromite about 2 feet wide. The chromite was hand sorted and cobbed from the dunite before shipping to the Yreka stockpile. From six to fifteen men were employed under H. E. Ellickson, manager. Production continued from the summer of 1942 to the fall of 1945 except for interruptions caused by bad roads in the winter. The grade averaged from 35 to 40 percent Cr_2O_3 with a 2.4 to 1 chromium to iron ratio. Much low-grade disseminated material was discarded. (O'Brien 43, p. 82; U. S. Geological Survey 43, p. 94; O'Brien 43a, p. 328.)

Flederman lease, in sec. 9, T. 44 N., R. 7 W., M. D., is owned by the Southern Pacific Land Company. Max Erwin of Yreka shipped about 30 tons of 51 percent Cr_2O_3 from this property in 1942. The chromite occurred in small lenses in serpentine and was mined from an adit driven N. 40° W. about 75 feet.

Genesis (Hayden) claim, in sec. 35, T. 42 N., R. 7 W., M.D., is owned by Southern Pacific Land Company, and leased to R. V. Hayden of Callahan. Ernest Hayden and Charles Thompson of Callahan followed a lens

of high-grade chromite in serpentine to a depth of 140 feet in a shaft inclined 70 degrees in a S. 67° W. direction. Ore from this shaft and from several other shallow shafts and pits averaged from 48 to 52 percent Cr_2O_3 with a 3.4 to 1 chromium to iron ratio. Shipments were made to the Yreka stockpile in 1942, 1943, and 1944. (O'Brien 43a, p. 328.)

Ladd (Red Mountain, Dolbear) mine, three claims in sec. 15, T. 46 N., R. 11 W., M.D., is owned by John Ladd of Seiad and leased to Mrs. Dorothea Reddy Moroney, Klamath River Post Office. The U. S. Forest Service built 4 miles of access road to this property in 1943. Chromite occurs disseminated and in bands in a tan-colored dunite. It was mined from short adits and shallow open cuts. Ronald Knudsen of Yreka had four men employed at this property in June 1943, building ore bins and a gravity tram 150 feet long, but only a small production of ore was made. There seemed to be a considerable quantity of low-grade chromite at this property. (O'Brien 43, p. 82; U. S. Geological Survey 43, p. 96; O'Brien 43a, p. 328.)

Lady Gray mine, three claims in sec. 30, T. 45 N., R. 10 W., M.D., is owned by Mrs. Dorothea Reddy Moroney of Klamath River Post Office. About 4 miles of access road was built to this property from the Scott Bar-Fort Jones highway. A 24-inch band of fine-grained chromite is said to assay 38 percent Cr_2O_3. From three to five men were employed in April 1945 building a road with a bulldozer and mining and stockpiling the ore from an open cut about 12 feet long, 11 feet wide, and 8 feet deep at the face. (O'Brien 43, p. 83.)

Lambert (Peg Leg) mine, in sec. 25, T. 44 N., R. 8 W., M.D., is owned by Basil Wild and Carl Johnson of Fort Jones. Flat lenses of high-grade chromite from 10 inches to 3 feet thick were mined from an adit driven S. 55° E. about 125 feet, and from bulldozer cuts along the bank. This property was mined under lease by C. F. Shaw of Yreka in January 1943. Three men were employed. In April 1945 the property was purchased by H. E. Ellickson and Nick Young of Yreka. A bench about 350 feet long, 70 feet wide, with a bank 10 to 15 feet deep, was cut with a bulldozer, during the mining and prospecting of this property. Chromite shipped to the Yreka stockpile is said to have assayed from 52 to 54 percent Cr_2O_3. (Logan 25, p. 424; Averill 35, p. 266; O'Brien 43, p. 83; 43a, p. 328.)

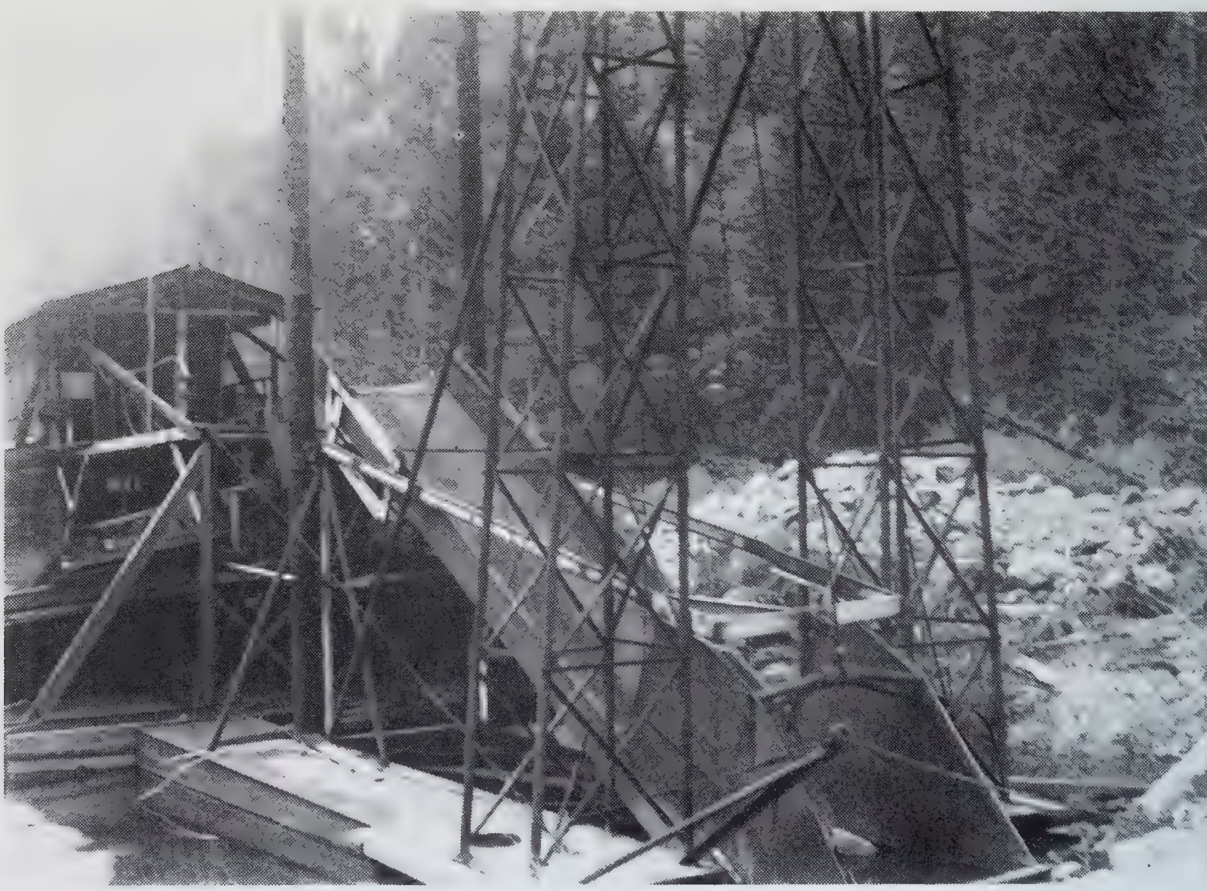
McGuffy Creek deposits, in sec. 25, T. 45 N., R. 11 W., M.D., and secs. 30 and 31, T. 45 N., R. 10 W., M.D., were mapped by the U. S. Geological Survey and drilled and sampled by the U. S. Bureau of Mines in 1942. Low-grade chromite occurs banded and disseminated in dunite over large areas. Some high-grade ore was mined from this area in 1918 but no production has been made since, because of the difficulty and expense of building a road to the area.

Seiad Valley deposit, four patented and 13 unpatented claims in secs. 7, 17, 18, 19 and 20, T. 47 N., R. 11 W., M.D., is owned by the Rustless Mining Corporation, a subsidiary of Rustless Iron and Steel Corporation, 3400 East Chase Street, Baltimore, Maryland. The U. S. Geological Survey and U. S. Bureau of Mines mapped and sampled this property in 1941. Diamond-drill holes 125 to 350 feet deep were drilled in a N. 30° E. direction, at about 80-foot intervals, for a length of 1380 feet. A drift from the west adit at an elevation of 3280 feet was continued for 200 feet. The U. S. Forest Service widened, graded, and improved

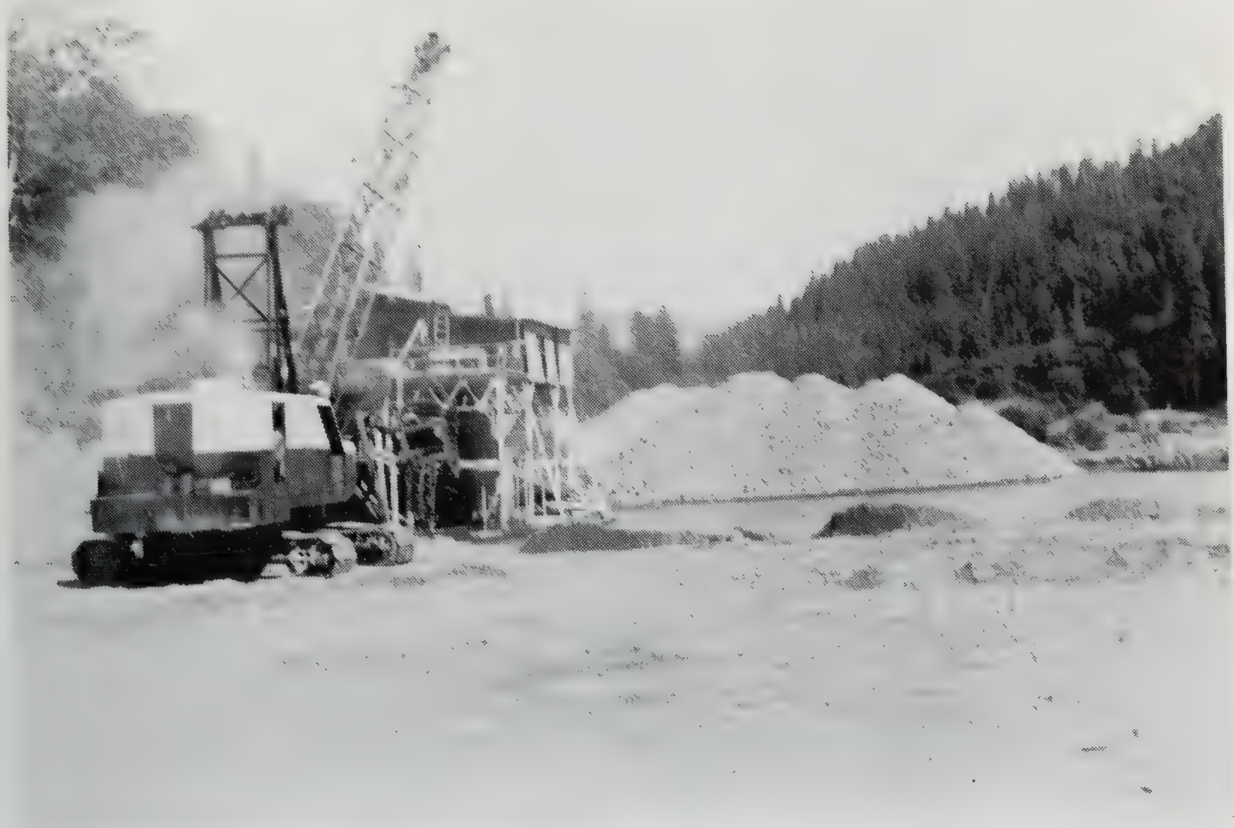
A, GRAY EAGLE COPPER COMPANY MILL
Near Happy Camp, Siskiyou County

B, CHENOWETH DREDGE
Klamath River near Hamburg, Siskiyou County

A, HUNTINGTON MILL
At Middle Fork Mines, Siskiyou County



B, SINGLE-BUCKET DREDGE
Midland Company, Incorporated, Siskiyou County



A, SCANDIA NO. 1 DREDGE
On Horse Creek, Siskiyou County

B, YREKA GOLD DREDGING COMPANY DREDGE
Klamath River Near Seiad, Siskiyou County

A, CRUSHING AND SCREENING PLANT
Of Electro Lime and Chemical Company at Gazelle, Siskiyou County

B, PUMICE PIT
Of Glass Mountain Volcolite Company, Siskiyou County

C, PUMICE CRUSHING AND CARLOADING EQUIPMENT
Of Allen Miers at Tionesta

7½ miles of road from Seiad to the property, and continued the road up the mountain to the Cook and Green Pass.

Chromite occurs banded and disseminated in dunite over a large area. During World War I several thousand tons of hand-sorted chromite said to average 48 percent Cr_2O_3 was shipped from this property by Dr. Reddy of Medford, Oregon. In January 1943 the Kangaroo Mountain Chrome Company obtained a lease from the Rustless Mining Corporation. Selected zones where a marketable grade of ore could be mined were assigned to miners and the ore they produced was purchased on the dump for $6 a ton. All tools, equipment, air, and powder were furnished by the company. J. A. and W. H. Young, Elmer Weeks and his brother, and other groups mined chromite from open cuts and short adits under James H. Suddreth, manager for the company. The chromite was shipped 60 miles to the stockpile at Yreka. (Averill 35, pp. 267-269; O'Brien 43a, p. 329.)

Simas Ranch, sec. 35, T. 44 N., R. 8 W., M.D., is owned by A. T. Simas of Yreka. Clem and Ben Baker of Yreka mined small lots of chromite from lenses in serpentine on this property in January 1944.

Snowy Ridge claim, in sec. 21, T. 48 N., R. 9 W., M.D., was leased and operated by James K. Remsen of Grants Pass, Oregon in 1942-43. Chromite was shipped 55 miles by truck to the Grants Pass stockpile.

Wild and Johnson deposit. Basil Wild and Carl Johnson of Fort Jones leased the N½ sec. 19, T. 42 N., R. 8 W., M.D., from the Southern Pacific Land Company. They shipped 120 tons of 53 percent Cr_2O_3 to the Yreka stockpile in 1943. The chromite was mined with a bulldozer from lenses of serpentine. (O'Brien 43a, p. 329.)

Coal

Occurrences of lignite and sub-bituminous coal have been noted in the Tertiary formations which outcrop east of Hornbrook in T. 47 N., R. 5, 6 W., and in the northwest quarter of T. 46 N., R. 5 W., M.D.

Hagedorn Ranch Deposit. About 30 years ago an incline shaft was sunk 700 feet on a soft coal seam dipping flatly east on the Hagedorn Ranch, 5 miles south of Ager. Three drifts were driven north and south a maximum distance of 500 feet on the coal. The thickness of solid coal is said to average 2 feet in a coal measure 6 feet wide.

A production of 100 tons valued at $500 was reported from this deposit in 1914 when it was under lease to the Yreka Development Company. There has been no production or development since then. (Averill 35, p. 270; Logan 25, p. 426.)

Cooley Ranch. A hole drilled 130 feet deep on the Cooley Ranch is reported to have cut 11 feet of coal. A second hole was said to have cut 20 inches of coal at 95 feet. (Averill 35, p. 270; Logan 25, p. 426.)

Siskiyou Coal and Coke Company had leases on ranches in Shasta Valley in 1925. A diamond-drill hole on the Herr Ranch, about a quarter of a mile north from the second hole on the Cooley Ranch, cored through alternate layers of sandstone and shale for 110 feet. (Logan 25, p. 426; Averill 35, p. 270.)

Copper

The urgent need for copper during the war led to the re-examination of many deposits that have been known for years. Several prospects were developed to a small extent and others were sampled, but only the Gray

Eagle mine in the Happy Camp district actually produced. The value of the copper produced from this mine far exceeded the gold produced in Siskiyou County in 1943-44.

Big Blue Claims. Two claims in sec. 36, T. 40 N., R. 9 W., M.D., were relocated in 1942 by Suzanne H. Hartley. Six quartz veins outcrop on these claims, which were located in a northeasterly direction along the slope of the mountain. The veins are from 3 to 12 feet wide and strike S. 65° to 77° W. and dip 70° to 80° S. They are sheared and cracked parallel to their strike, probably because of the intrusions of diorite and periodotite with which they are in contact in some instances. Sulphide solutions deposited bornite, chalcocite, and some chalcopyrite in the seams and cracks. There has been some oxidation to form malachite and azurite. No pyrite was noted. Only shallow development has been done on these claims and no assays from representative samples were reported.

Blue Ledge mine includes 26 patented claims 33 miles southwest of Jacksonville, Oregon, in sec. 3, T. 47 N., R. 11 W., and sec. 34, T. 48 N., R. 11 W., M. D. It is owned by the Mexican Mining and Refining Company, 120 Broadway, New York, N. Y. During the last period of operation (1920), some 9000 tons of sorted ore, said to average 13.7 percent copper, 5.5 ounces of silver, and 0.1 of an ounce of gold, was shipped. A vein averaging 5 feet in width, striking north and dipping 60° W. was developed for a length of 1500 feet by drifts and four adits, and by raises and winzes. Chalcopyrite is the principal ore mineral and it occurs with pyrite. Both walls of the vein are micaceous schist.

The U. S. Geological Survey and U. S. Bureau of Mines mapped and sampled this property in 1942, but no report of their examination has been published to date. The owners estimated 240,000 tons of ore, averaging 4.8 percent copper, 0.35 of an ounce of gold, and 1.5 ounces of silver, were blocked out in 1920. (Brown 16, p. 817; Laizure 21, p. 530; Tucker 23, p. 8; Logan 25, p. 427; Averill 35, pp. 261, 271; Aubury 05, p. 108; Hamilton 22, pp. 12,14.)

Copper Creek (Blue Bell) group of six claims in sec. 31, T. 16 N., R. 8 E., H., is owned by I. D. Turner of Redding. On Copper Creek No. 1 claim, a vertical shaft about 12 feet deep cut through a shear zone in andesite 8 feet wide, in which there are three bands of copper minerals from 2 to 12 inches wide replacing pyrite. The bands strike N. 15° W. and dip 15 to 20° W. Chalcopyrite, malachite, and some sphalerite occur with pyrite. A sample across 8 feet is said to have assayed 3 percent copper and 1 percent zinc. The prospect is reached by a 1½-mile trail southeast from Elk Creek. It is idle except for assessment work.

Copper King group, in sec. 20, T. 40 N., R. 7 W., M.D., consists of four claims owned by Norma B. Wilson. They are developed by an adit driven N. 23° E. about 300 feet on a quartz vein 8 feet wide, which dips 73° W. Above the adit, an old shaft 15 feet deep is said to have yielded 50 tons of ore assaying 5 percent copper and $8 in gold. The principal copper mineral is chalcopyrite and it is associated with pyrite. Both walls are serpentine. In the summer of 1943 the property was leased by Max Erwin of Yreka. James K. Remsen of Grants Pass reopened and timbered some of the caved workings for examination and sampling, but no production resulted.

Copper Mountain Group. Five claims in the Dillon Creek district are owned by Forest Moore, A. W. Scott, and George Russell of Happy Camp. They are a relocation of the Virginia claims once owned by Hugh

Wright. These claims are said to have a very large gossan outcrop but their development has been handicapped because they have no access road.

Facey Mine. One patented claim in the SW¼ sec. 23, T. 41 N., R. 9 W., M.D., is owned by Facey Brothers of Etna. It was leased in 1941 to Elwood and W. B. Stewart of Etna. Three men were employed mining copper carbonate and oxides from a vein 3 feet wide striking S. 60° W., and dipping 77° N. Both walls were gray lime-shale. An old adit driven N. 70° W. for 80 feet had a narrow vein in the face and a raise 30 feet high. The property was equipped with a wooden ore bin 15 feet square and 11 feet deep. A single cylinder "hot head" engine converted as a compressor was driven by a four-cylinder Ford engine and supplied compressed air for a jackhammer. Tinken bits were used. The property was operated a very short time, and so far as is known, no ore shipments were made.

Gray Eagle (Dakin) mine, 32 claims, mostly patented, in secs. 13, 14, and 23, T. 17 N., R. 7 E., M.D., are owned by the Gray Eagle Copper Company, a subsidiary of the Newmont Mining Corporation, 14 Wall Street, New York, N. Y. When this mine closed in 1919, a million tons of copper ore were said to be blocked out. The current low price of copper and the high cost of operation, owing to the distance from railroad and smelter, made this reserve unprofitable to work.

The Gray Eagle Copper Company reopened the property in December 1941, with Robert J. Hendricks as manager, W. P. Goss as assistant manager, and a staff including Duncan L. King, mill superintendent; W. E. Meals, plant designer; H. J. Steele, mining engineer; Jack Widauf, mine foreman; E. H. Tucker, chief electrician; Howard Johnson, master mechanic; and F. A. Scheck, chief clerk and purchasing agent. The road up the mountain from Indian Creek was widened, graded, and improved for about 2 miles. Sites were graded for mine plant, camp, and office buildings. The No. 7 adit was widened to an 8- by 9-foot section; 35-pound rails were laid for 30-inch gauge track; a 6-inch air line and 2-inch water line were installed, as well as two armored cables carrying electric power at 440 volts.

The ore body was roughly almond shaped and about 800 feet long, 400 feet wide, and from 6 to 70 feet thick on the edges and in the center, respectively; dip was about 25° N. Chalcopyrite was the principal copper mineral and it was a replacement of pyrite in a pyritic schist.

A station was cut on the west side of the haulage-level adit, and a raise 240 feet high was run to the ore. The raise was timbered with 8- by 8-inch square timbers, and divided into a 6- by 5-foot hoisting compartment; a 3½- by 5-foot manway in which the 6-inch air line, 2-inch water lines, and 440-volt armored electric cable were installed; and a 4- by 5-foot waste chute. A single-deck cage was used to hoist men and supplies. It was operated by a single-drum hoist on the station, powered by a 60-horsepower electric motor. Four levels were run at 50-foot intervals on the south side of the raise, and one on the north side under the ore body. These levels were run from edge to edge of the ore body and were about 400 feet long. Entry crosscuts 50 to 200 feet long were run in waste to the ore, and 65-degree incline raises 6 by 6 feet in section, spaced at 60 foot intervals, were run through the ore.

Four untimbered ore passes, 6 by 9 feet in section, spaced 100 to 150 feet apart, were run from the haulage level to the crosscuts. The ore

passes were covered at the top by a 90-pound grizzly with rails spaced at 12 inches. The loading chutes at the haulage level were lined with steel sheets on 12- by 12-inch timbers, and had a slope of 40 degrees on the bottom. Steel ore gates were operated by air cylinders. The ore was loaded into Granby-type cars, capacity 80 cubic feet, and trains of 12 cars were hauled by a 6-ton storage-battery locomotive to the ore bins. The battery-charging station was cut on the south side of the haulage adit near the shaft station.

The ore body was mined by the room and pillar system, and the stopes were untimbered except for occasional stulls. About 5 percent of the ore was estimated to have been left in pillars. Holes were drilled with 3-inch automatic-feed drifters mounted on air-feed bars. Blasting was done with 40 percent ammonia gelatin detonated by fuse and caps.

Detachable bits were used with 1⅛-inch round steel. The broken ore in the stopes was scraped into the inclined raises and flowed into the crosscuts where it was again scraped into the ore passes and dropped to the haulage level. The stope scrapers of 42 and 48 cubic feet capacity were operated by 20- and 30-horsepower double-drum electric hoists. The crosscut scrapers were 60 cubic feet capacity and powered by 50-horsepower double-drum electric hoists. Raises holed to the surface provided natural ventilation.

The mine was operated on two 8-hour shifts: 8 a.m. to 4:30 p.m., and 6:30 p.m. to 3 a.m., with half-hour lunch periods. Miners worked on a contract price per ton or cubic-foot basis, and contracts were for a 2-week period. In October 1944 the miners were earning an average of $12.06 per day. Housing accommodations were built at Happy Camp by the Federal Housing Bureau. Board and room cost $1.60 per day, and houses for families were rented for $27.50 to $41.00 per month, completely furnished, and including water, lights, and heat.

The milling plant was located a short distance west of the portal, and Duncan L. King, mill superintendent, was in charge. The side-dumping ore cars were dumped automatically into a wooden crib-type, 500-ton-capacity, coarse-ore bin. A 3½- by 7-foot Utah vibrating feeder fed plus 2-inch material to a 24- by 36-inch Traylor jaw crusher set to deliver a minus 2-inch product to the No. 1 conveyor belt. A 37-inch Cutler-Hammer electro magnet was suspended over the belt to remove tramp steel. No. 1 conveyor was discharged into No. 2 conveyor which fed a 3- by 6-foot Symons rod deck screen. Material over nine-sixteenths was delivered to a 3-foot standard Symons cone crusher. The plus three-eighths minus nine-sixteenths material was fed into a 4-foot short-head Symons cone crusher. The minus three-eighths-inch material from the Symons screen was discharged into No. 5 conveyor for delivery to the fine-ore bin. The product from the cone crushers was screened on a 4- by 8-foot Symons rod deck screen. Minus three-eighths-inch material was discharged into the No. 5 conveyor belt and delivered to the fine-ore bin. Plus three-eighths-inch material was returned to the 4-foot short-head cone crusher.

The fine-ore bin had a capacity of 2000 tons of minus three-eighths-inch ore. It was loaded by a hand-operated tripper on a 160-foot horizontal conveyor belt. The flow of ore from the fine-ore bin was controlled by two size "C" Hardinge constant-weight feeders. Two No. 77 Marcy ball mills loaded with 3-inch balls were driven at 24½ revolutions per minute by 200-horsepower motors. They were in closed circuit with two 72-inch Wemco spiral classifiers. The classifier overflow was about 20

percent solids. About 90 percent of the ore was ground to minus 200-mesh, and 1½ pounds of lime per ton of ore was added to the ball mills, and another pound of lime per ton was added to the conditioner. Reagents 238, 242, C-3, and C-5 were used as promotors, and DuPont B-23 as a frother.

Three banks of five 56-inch Fagergren flotation cells were used. The first two banks of cells were used as roughers from which the tailings went to the waste pond; concentrates went to a Denver 6- by 6-foot conditioner before being fed to the five cleaner cells. The feed to the cleaner cells was about 12 percent solids. The concentrates were first pumped by a 2-inch Wemco sand pump to a 35- by 12-foot Dorr thickener—then by a No. 2 Dorr duplex diaphragm pump to a 6-foot, five-leaf Eimco disc filter.

The tailings from the cleaner cells were pumped by a Hydroseal sand pump to a 7-foot Callow cone; underflow was returned to the ball mills, overflow was used for pulp dilution. Water from the disc filter was pumped to the mills water tank and the concentrates containing about 9½ percent moisture were stored in a 175-ton bin equipped with a 14-inch screw conveyor for loading conveyor buckets or trucks. An aerial tramline 3.4 miles long ran over the mountain to a terminal at Thompson Creek and eliminated about 20 miles of trucking. Each tram bucket held a cubic foot of concentrates. At the terminal, the buckets were discharged into bins holding a truck load of 10 tons each. It was about an 80-mile haul to the railroad siding at Yreka, where the trucks were discharged into a 65-ton bin. An 18-inch shuttle conveyor from this bin discharged into a box-car loader, which had a capacity of about 50 tons per hour. The concentrates were shipped to the American Smelting & Refining Company smelter at Tacoma.

About 465,000 tons of 3 percent copper ore were mined and milled at this plant between March 1943 and July 1945, when the operation ended.

The ore body is considered worked out and the mine plant, machinery, and equipment have been removed. (Brown 16, pp. 817, 825; Laizure 21, p. 531; Tucker 23, p. 8; Logan 25, p. 428; Averill 35, p. 272; O'Brien 43, p. 83; 43a, p. 329.)

Mammon group, see under *Gold.*

Polar Bear claim, in sec. 12, T. 40 N., R. 8 W., M. D., is owned by Byron Burch of Seattle, and was leased to Winters and Heath of Yreka in 1943. Small amounts of chalcopyrite occur with pyrite in serpentine. Nine men were employed retimbering an old two-compartment vertical shaft said to be 210 feet deep, and in reopening an old caved adit driven N. 85° W. for 120 feet. The property was equipped with a portable compressor, pumps, and jackhammers. A bulldozer was used to prospect the surface. The operation was short lived. Some sorted material hauled to Yreka was said to have assayed too low for shipment to a smelter. (Brown 16, p. 819; O'Brien 43a, p. 329; Aubury 05, p. 106.)

Preston Peak mine. Five patented claims in sec. 22, T. 17 N., R. 5 E., H., are owned by Edgar Wallace of Los Angeles. The property is reached by about 3 miles of trail from the road at Cyclone Gap 23 miles from Waldo, Oregon. The main adit was driven about 400 feet S. 16° W. in diorite, with crosscuts east and west at 150 feet. A winze 40 feet deep was sunk from the east crosscut, and a crosscut driven S. 30° E., 32 feet from the bottom. The winze was sunk on a quartz diorite dike which is 30 feet wide, strikes S. 36° E., and dips 80° NE. The quartz diorite

includes a large amount of pyrite, but no copper minerals were recognized. It is probable that this adit was driven in search of some copper mineralization showing in the cut at the portal of a short adit lying above and southwest of the portal of the main adit.

This short adit was driven about 20 feet N. 80° W. in quartz diorite including a large amount of pyrite. In the cut to the adit about 20 feet of ore was cut, said to assay 4 percent copper. The copper minerals were chalcopyrite, bornite, and some covellite, associated with pyrite.

This property was examined by geologists of the U. S. Geological Survey and mining engineers for the Reconstruction Finance Corporation in 1942, but no development work was undertaken. (Brown 16, p. 819; Maxson 33, pp. 139, 146; Aubury 05, p. 110.)

Yellow Butte mine covers 318.14 acres of patented land in the W½ sec 25, T. 43 N., R. 4 W., M. D. It is assessed to the Lone Hill Mining Company, W. E. Hills, 845 Jefferson Court, San Mateo, California, president. The incline shaft is caved and the old workings are inaccessible, but the dump shows specimens of white quartz containing pyrite, chalcopyrite, and some molybdenite. (Brown 16, p. 820; Averill 35, pp. 273, 333; Aubury 05, p. 107; 08, p. 126.)

Gold

The production of gold in Siskiyou County reached a peak of $2,351,790 in 1941, the last full year of operation before World War II.

Rising wages, the enlistment of miners in the armed forces or defense industries, difficulties in obtaining supplies, materials, and equipment, increased taxes, and governmental restrictions made it necessary to close almost all of the gold mines early in 1942. On October 8, 1942, War Production Board Order L-208 closed the few surviving mines, and in 1943 gold production in the county dropped to $110,040.

Much of the machinery and equipment used by the dredges, such as draglines, bulldozers, carryalls, electric motors, and rubber belts, was transferred to the war industries.

Gold mining has been slow to recover since it was permitted to resume operation in July 1945. The scarcity of men and materials, high wages, and taxes have made mining costly; and the price of gold has not been raised to offset the increased costs.

Abe Lincoln No. 2 placer, located on the south side of the Klamath River in sec. 6, T. 46 N., R. 12 W., M.D., is owned by Al Livingston of Fort Goff. It was last operated in a small way in 1938. (Logan 25, p. 462; Averill 35, p. 314.)

Anna Johnson and Surprise. Two unpatented claims located in the Liberty mining district, in sec. 10, T. 39 N., R. 11 W., M.D., are owned by Alex Markon of Sawyers Bar. A crushed and brecciated quartz zone has been developed by three adits driven in an easterly direction for 98, 100, and 170 feet. A fourth adit, about 350 feet northeast and 300 feet higher, which strikes S. 10° W., penetrated a crushed quartz ledge for 100 feet. This ledge is 12 feet wide, and is said to average $10 per ton in gold.

The property is equipped with a Kroch two-stamp mill with 1500-pound stamps that drop 5 inches. The ore was crushed to 25-mesh and was run over a 4- by 6-foot copper plate. Power was had from a 1924 Dodge automobile engine. A concrete arrastra 4 feet in diameter was powered by a single-cylinder gasoline engine. Markon was working alone when the property was visited in June 1945.

Autumn mine includes four claims in sec. 2, T. 40 N., R. 9 W., M.D., 4 miles north of Callahan. It is owned by I. B. Sovey and A. E. Hughes of

Callahan. A quartz vein 16 inches wide on the contact of serpentine and porphyry strikes northeast and dips vertically. It is developed by a two-compartment vertical shaft 124 feet deep with levels at 30 and 60 feet. The vein is white quartz stained red with ochre. Sorted ore is said to have assayed from $90 to $200 per ton in free gold. The vein has been stoped on the 30-foot level for 40 feet north of the shaft. On the 60-foot level, drifting on the vein has progressed 80 feet south and 120 feet north. There is some 40 feet of water in the shaft.

Three parallel veins 1 to 18 inches wide strike east and dip south on these claims; they are said to assay up to $45 per ton. There is a gallows frame of 10- by 10-inch square timbers and a frame hoist house covered with corrugated iron at the shaft. The property has been idle in recent years.

Beaudry placer in sec. 35, T. 40 N., R. 9 W., M.D., is owned by the Angele Bazet estate, c/o Marie B. LaPorte, Administratrix, 4 Laguna Street, San Francisco, California. Alexis Bourier of Callahan operated this mine a few months in the spring of 1942. He used a No. 1 giant with a 160-foot head against a 20-foot bank of gravel above serpentine bedrock. This gravel deposit is about 100 feet higher than the present channel of Fox Creek, a tributary to the South Fork of Scott River. The property is now idle. (Brown 16, p. 844; Logan 25, p. 464; Averill 35, p. 314; Haley 23, p. 99.)

Beaver Dredging Company. Leslie G. Allen, dredgemaster and part owner, operated a dragline dredge on Beaver Creek in sec. 30, T. 47 N., R. 8 W., M.D., in the summer of 1941 on land owned by Ray Taber. Equipment included a 1201 Lima dragline powered by a Cummins Diesel-228 motor and having a 70-foot boom and a 2¼-cubic-yard Esco bucket. The Judson Pacific washing plant had six steel pontoons making a barge 35 by 42 feet, 42 inches deep. The trommel was 60 inches in diameter and 30 feet long, with 20 feet of one-half to seven-eighths inch screen. The stacker belt was 30 inches wide and 65 feet long. Water was supplied by a 10-inch United Iron Works centrifugal pump. Gold was recovered in sluice boxes fitted with Hungarian riffles. The power plant included a Caterpillar D-13000 engine and a Palmer generator. An Allis Chalmers crawler-type bulldozer was used to clear the land of trees and brush. The gravel was 9 feet deep above serpentine bedrock, and 1800 cubic yards were dug by a crew of nine men in two 9-hour shifts. The plant and equipment were moved to Indian Creek near Fort Jones in Siskiyou County after only 6 weeks of operation on Beaver Creek.

Bendl Mine. Richard Bendl owns four claims about 6 miles east of Forks of Salmon, in sec. 5, T. 39 N., R. 12 W., M.D. Water for a No. 1 giant with a 2½-inch nozzle is obtained under 140 feet of head from Big Creek. The gravel bank is 20 feet high. There are 60 feet of sluice boxes 18 inches wide fitted with block riffles. Bendl operates the property alone when sufficient water is available.

Black Bear quartz mine owns 70 acres of patented land and some 29 claims by location about 7 miles southwest of Sawyers Bar, in sec. 13, T. 39 N., R. 12 W., and secs. 7 and 18, T. 39 N., R. 11 W., M.D. The mine has been idle for many years but it has produced about $3,100,000 in gold since its discovery in 1860. The property was purchased in 1945 by the Yreka Mining Company, c/o S. F. Jackson, Yreka. (Irelan 88, pp. 620, 695; Hobson 90, p. 656; Dunn 93, pp. 424, 429, 431; Crawford 94, p. 277; 96, pp. 389, 434; Brown 16, pp. 822, 826; Hamilton 22, p. 18; Tucker 23, p. 10; Logan 25, p. 431; Averill 35, pp. 274, 315; Logan 19, pp. 85, 73, 77.)

Buzzard Hill Mine, Inc. (J. E. Merriam, Bedford Hills, New York, president, Philip M. Toleman, Happy Camp, manager), consists of twelve unpatented claims located in secs. 4 and 5, T. 15 N., R. 7 E., H., and seven claims in sec. 32, T. 15 N., R. 7 E., H., (Independence mine) which were leased in 1941 to the Merriam Mining Merger, a partnership including J. E. Merriam, J. E. Merriam, Jr., and Philip M. Toleman. In July 1941 Toleman and four men were mining and cyaniding about 30 tons of gossan ore a week. The gossan was irregular in shape but appeared to be confined to a shear zone above a massive pyrite deposit striking northeast and dipping flatly east. The ore was crushed to one-eighth inch and leached 8 days in a sodium cyanide solution. Precipitation was done in zinc boxes. An 80 percent extraction was claimed for ore assaying $17.15. The property is idle. (Logan 25, p. 428; Averill 35, p. 276.)

C & E Dredging Company (A. B. Cutler, president, 315 Corbett Building, Portland, Oregon, Hugh Williamson, manager). The dredge was located on McAdam Creek about 8 miles north of Fort Jones on land leased from W. Stevens. The operation started in May 1941 on old hydraulic tailings in sec. 30, T. 45 N., R. 8 W., M.D. Equipment included a Lima dragline with a 65-foot boom and a $2\frac{1}{4}$-cubic-yard bucket powered by a Waukesha engine. The washing plant was built on six steel pontoons making a barge 36 feet wide, 48 feet long, and 42 inches deep. The trommel was 60 inches in diameter and 36 feet long with 20 feet of three-eighths to nine-sixteenths inch perforations. The stacker belt was 30 inches wide, 50 feet long and was run 320 feet per minute. Power was obtained from a D-1300 Caterpillar engine. Gold was saved in sluices fitted with Hungarian riffles and expanded metal lath over cocoa matting. The gravel was about 24 feet deep above a hard porphyry bedrock and ran from 12 to 35 cents per cubic yard. Boulders were plentiful. Thirteen men were employed on two 9-hour shifts. Operations were suspended on December 31, 1941. The dragline, bulldozer, and much of the equipment were moved away to war industries.

California American Mining Company. A group of ten claims in sec. 31, T. 47 E., R. 6 W., M.D., is owned by the P. J. McCavick estate, c/o William McCavick, Kansas City, Missouri. Quartz stringers and narrow veins occur in a red, yellow, and brown seamed andesite. The deposit has been prospected by many shallow cuts and a few short adits and shallow shafts. The quartz carries considerable pyrite in places where it is near the contact with a tan-colored shale. There is no record of production from this property, but mapping and sampling may disclose areas that can be mined profitably.

Cal Oro Dredging Company (Gardella Dredge). This bucket-line dredge is located just east of Highway 99 north of Yreka on land owned by A. Young. It has been idle since 1940 and is assessed to the E. Tubbs Estate, c/o Bank of America, Yreka. (Averill 35, p. 282; 38, p. 114.)

Chambers Hydraulic Mine. J. A. Chambers and Associates were leasing the hydraulic mine on the Ball Ranch about 3 miles northeast of Cecilville in sec. 15, T. 38 N., R. 11 W., M.D., in February 1947. Water was brought from Taylor Creek through 1800 feet of ditch and delivered to a No. 2 and a No. 4 giant under a 165-foot head through 900 feet of 15-inch pipe. The bank is 45 feet high above a slate bedrock with about 20 feet of overburden. There are 36 feet of sluices, 24 inches wide with 36-inch sides fitted with wood block riffles. One man was employed.

Chenoweth Brothers dredge is owned by a partnership composed of Kenneth and Edward Chenoweth of Hamburg, Carroll Monroe, Edward Woodzake, and Roy Thornton. They have a dragline dredge on the south bank of the Klamath River in sec. 27, T. 46 N., R. 11 W., M.D., about 3 miles west of Hamburg on 155 acres of land leased from Mrs. E. R. Titus. Four steel pontoons make a barge 32 by 20 feet. The trommel is 50 inches in diameter, 20 feet long, and has a 16-foot length of five-eighths inch screen. It is driven by a 6-cylinder Chevrolet motor. The stacker belt is 20 inches wide, 40 feet long, and is driven by a single-cylinder Wisconsin motor. Water is supplied by a LaBoure 6-inch centrifugal pump driven by a Wisconsin gasoline engine. There are three downstream and five cross sluice boxes on each side fitted with Hungarian riffles. A 5-inch Byron-Jackson centrifugal pump powered by a 4-cylinder Buick engine pumps water from the river to the pond for the washing plant. The gravel is from 20 to 40 feet deep above a hard bedrock. It will be dug by an oil- or wood-fired steam-powered Erie dragline with a 54-foot boom and a $1\frac{1}{4}$-cubic-yard bucket. The operation was about ready to start in February 1947.

Cherry Hill mine includes fourteen quartz and two placer claims in sec. 27, T. 45 N., R. 8 W., M.D. It is owned by F. G. and Carl V. Reichman and leased to G. A. Reichman, Box 122, Yreka. On the Ironside claim, a quartz vein in greenstone averages 2 to 20 inches in width, strikes S. 15° W., and dips 83° E. It is offset from 8 to 25 feet at intervals by faults striking N. 65° W., and dipping 60° N. It is developed by four adits, the longest of which is some 450 feet. The vein averages about 10 inches in width and has been stoped 80 to 100 feet to the surface for a length of 300 feet. Compressed air is delivered by an 8- by 8-inch Sullivan compressor and the rock is drilled with mounted jackhammers and steel equipped with Timken bits.

The ore is hauled about a quarter of a mile to a five-stamp mill and crushed to 50-mesh. The gold is saved by amalgamation on plates, and concentrates are saved on a Wilfley table. The ore is said to have milled $50 in free gold, and the sulphide concentrates average about $400 per ton. Some rich specimens of free gold have been found occurring with pyrite and galena. George Reichman and four other men mined and milled about 15 tons per month in 1941. The mine and mill have electric power from the California-Oregon Power Company.

The property was subleased in 1944 to the Crystal Creek Mining Company, controlled by H. F. Lintner and A. O. Witte of Redding. Some additional development was done drifting on the vein on No. 4 adit level and at the bottom of a 25-foot winze. The Wadsworth adit, 75 feet lower, was extended S. 15° W. to 200 feet and then a crosscut was driven west to a 6-inch vein striking S. 20° W. and dipping 45° E. The vein was followed a short distance south but the raise to connect with the Ironside adit was not run. The mine is idle. (Brown 16, p. 829; Logan 25, p. 436; Averill 31, p. 31; 35, pp. 276, 316.)

China Point placer in secs. 5, 6, 7, and 8, T. 16 N., R. 8 E., M.D., is owned by C. E. Regan of Happy Camp. It was operated on a small scale for a short period in the spring of 1942. Idle. (Averill 35, pp. 277, 316.)

Classic Hill mine holds some 1500 acres, of which about a third are patented, in sec. 36, T. 18 N., R. 6 E., H. It is owned by C. Scott Greening, c/o C. D. Wason, Happy Camp. In May 1937 the Happy Camp Placers, Incorporated, J. P. Morgan, president, 1003 Joshua Green

Building, Seattle, Washington, were operating the property. Water was obtained by $3\frac{1}{2}$ miles of ditch from the west fork of Indian Creek and from Tom Grey Creek. It was delivered under 260-foot head to two No. 2 giants with $4\frac{1}{2}$-inch nozzles. Four men were employed under A. C. Hahn, general manager, Happy Camp. The operation was short and no production was reported. (Crawford 96, p. 394; Brown 16, pp. 825, 846; Logan 25, p. 466; Averill 34, p. 306; 35, pp. 277, 316, 333.)

Conzetti quartz mine, on the upper South Fork of the Salmon River above Cecilville is owned by Ace Mills and leased with an option to purchase to J. A. Chambers and associates of Cecilville. An 18- to 28-inch quartz vein has been developed by several short cuts and adits. The outcrop was being stripped with a bulldozer in February 1947 so the vein could be sampled for possible development and mining. (Tucker 23, p. 10.)

Corbett gold (*Trust Buster mine*) includes two quartz and one placer claim and mill site in secs. 3 and 10, T. 47 N., R. 8 W., M.D. It is owned by J. L. Corbett of Hilt, California. Number 4 adit, at an elevation of 4100 feet, was driven N. 10° E. for 1500 feet. At 1200 feet a quartz vein $3\frac{1}{2}$ feet wide, with granodiorite walls, dips vertically. A vein 5 feet wide at 1275 feet dips 55° N. This adit level is some 565 feet below the apex of the vein. An adit at a higher elevation is said to have been driven for 500 feet along the granodiorite hanging wall of the vein, which had a width of 8 to 10 feet and averaged $7.50 in sulphides. Equipment included a 10- by 8-inch Ingersoll-Rand portable compressor and mounted air drills. A cyanide test is said to have recovered 97 percent of gold on ore crushed to 60-mesh. The property is idle. (Averill 35, pp. 261, 317.)

Crouch mine, owned by Everett and Frances A. Crouch, consists of the Jacque Girl, Derby quartz claims, and the Log Cabin placer claim, in the Humbug Creek district. Three quartz veins from 12 to 36 inches wide are developed by a single-compartment shaft 80 feet deep, and an adit 130 feet long. In 1946 the claims were leased to A. O. Witte of Redding with an option to purchase.

Crumpton placer consists of 240 acres of patented land in sec. 2, T. 16 N., R. 7 E., H., owned by Leonard, Cliff, and Jack Crumpton of Happy Camp. Water is brought from Ranch Creek through about a mile of ditch to a reservoir and delivered to the giants through 1500 feet of steel pipe under a 200-foot head. There are 900 feet of sluice boxes 18 inches wide and 2 feet deep fitted with block riffles. The bank is about 70 feet high with about 30 feet of red soil overburden above a black schist bedrock. A great quantity of the bank has slid down into the gravel pit. The property was idle but equipped to operate in November 1946. (Averill 35, pp. 275, 317.)

Crystal Creek Mining Company, see Cherry Hill mine.

Curran Mine. E. J. Curran owns 120 acres on the south side of the North Fork of Salmon River about 2 miles below Sawyers Bar. A high channel some 60 feet above the river has about 20 feet of gravel above a clay and sepentine bedrock. Water under a 180-foot head is brought from Jessup Gulch through half a mile of ditch, and 1100 feet of flume. Gravel is washed with a No. 2 giant and the gold is recovered in 300 feet of sluice boxes 18 inches wide and 2 feet high, fitted with 8-inch block riffles. Curran was working alone and moving about 60 yards per day in the 1941 season.

Dania Mine. Larsen Brothers and Harms Brothers, Route 4, Box 2220, Sacramento, California, operated a dragline dredge on the Klamath River in sec. 7, T. 46 N., R. 7 W., M.D., on ground included in the Clyburn placer. Equipment included a 5-cubic-yard Marion-Walker dragline with a 100-foot boom, and powered with a 300-horsepower Fairbanks-Morse engine. The boat was built by Hickinboatham Brothers of Stockton and was made of seven steel pontoons covering an area 8 feet by 36 feet, and had an additional 4 feet added to each side to make a barge 64 by 36 feet in area. The washing plant had a trommel 60 inches in diameter, and was 40 feet long with a 30-foot length of one-half to three-eighths inch screen. Water was supplied by a Byron-Jackson 10-inch centrifugal pump. The stacker belt was 36 inches wide and 100 feet long. Power was furnished by a D-17000 Caterpillar diesel. Hungarian riffles with mercury traps were used to save the gold. The gravel was about 35 feet deep, and about 4000 cubic yards per day was being dug in July 1941. Twelve men were employed on three shifts under R. J. Barrett, dredgemaster. This operation was closed down and much of its equipment moved to war industries in the summer of 1942.

Donnelly placer holds 40 acres in sec. 7, T. 16 N., R. 8 E., H., on the west bank of the Klamath River. It is owned by C. E. Reagan of Happy Camp. A gravel bench about 25 feet above the river is about 300 feet wide, and gravel is 14 to 60 feet deep above a greenstone bedrock. A Byron-Jackson 8-inch centrifugal pump driven by a 6-cylinder Fageol gasoline engine, coupled with a 4-cylinder Waukesha gasoline engine, furnished water for a No. 2 giant. Wash water was supplied by a Worthington 12-inch centrifugal pump. There were 60 feet of 2- by 2½-foot sluice boxes fitted with block riffles. Test pits are said to have indicated an average of 25 cents per yard for the gravel. The property was under lease to the Hillside Gold Company and sub-leased to the Joyce Gold Company, Joyce Hittson, Box 351, Huntington Beach, California, in November 1946. It was idle when visited November 14, 1946.

Eliza group of four claims and mill site in secs. 4, 5, 8, and 9, T. 45 N., R. 8 W., M.D., is owned by the DeWitt and Lawson Estate of Yreka and is leased to the Gold Crown Mining and Milling Company, Seattle, Washington. W. H. Price of Yreka is vice-president and general manager. The mine plant at the portal of No. 5 adit includes an Ingersoll-Rand 10- by 12-inch compressor geared to an 8-cylinder automobile engine, a Gardner-Denver portable compressor Model 9xJ20, 2 Sullivan stopers, a Sullivan drifter, and accessory equipment sufficient to develop and mine on a small scale. The milling plant included a 6- by 6-inch Blake crusher, a 40- by 40-inch Marcy ball mill, screen classifier, Mineral Separation jig, and five Mineral Separation flotation cells. Power is furnished by a variety of gasoline and diesel engines. Water flows to the mill from springs on the hill above.

The No. 5 adit was driven S. 10° W. for 260 feet, where it cut a 3-foot quartz vein striking S. 18° W. and dipping 78° W., with black fault gouge on both walls. The vein is laminated and stained brown and black. Throughout several hundred feet of drifting the vein has showed few changes in width and only minor offsets from faulting. A former operator estimated that it would average $5 in gold per ton. The fourth level is said to be 137 feet vertically above No. 5, and no stoping has been done between levels. The free-milling portion of the vein above No. 4 level has been stoped and is said to have yielded $150,000 when treated by amalgamation in a 10-stamp mill. No new development work has been done

on this property, aside from assessment work, in recent years. (Brown 16, p. 831; Tucker 22, p. 297; 22a, p. 600; 23, p. 11; 23a, p. 138; Logan 25, p. 439; Averill 31, p. 32; 35, pp. 280, 318.)

Enterprise placer at Scott Bar in sec. 21, T. 45 N., R. 10 W., M.D., is owned by Hollis Anderson and associates of Scott Bar. It includes portions of an ancient channel of the Scott River high above its present level. It was worked as a drift mine from an adit said to be 1000 feet long in 1888. No new work has been done at this property in recent years. (Crawford 96, p. 399; Logan 25, p. 439; Averill 35, p. 281.)

Etna Gold Dredging Company is controlled by William A. Kettlewell and W. S. Mead, 1730 Franklin Street, Oakland, California. A Walter Johnson bucket-line dredge was operated on Wildcat Creek about 2 miles northwest of Callahan in sec. 13, T. 40 N., R. 9 W., M.D., from December 1939 to December 1941. The dredge was built on 19 steel pontoons, making a hull 36 by 80 feet. The digging ladder was 60 feet long, and the chain of 79 3-cubic-foot buckets was driven by a 75-horsepower electric motor. The trommel was 54 inches in diameter and 25 feet long, with 19 feet of three-eighths to 1-inch holes, and was rotated by a 15-horsepower motor. The stacker belt was 24 inches wide and 70 feet long between pulleys. It was operated by a 15-horsepower electric motor. There were five cross sluices 29 inches wide by 14 feet long discharging into two downstream sluices, 36 inches wide and 24 and 30 feet long, fitted with Hungarian riffles on each side. There were mercury traps under the cross sluices. Water was pumped with a Byron-Jackson 10-inch centrifugal pump driven by a 60-horsepower electric motor. A 3-inch centrifugal pump driven by a 10-horsepower motor supplied water for the clean-up and for fire protection. The Johnson winch was operated by a 25-horsepower General Electric motor. The friction brakes had an automatic air-control device to set them in case of power failure. Boulders over 20 inches in size were by-passed to starboard before entering the trommel, and there were two rock chutes at the stern to discard rocks before they reached the stacker belt. The gravel was from $8\frac{1}{2}$ to 27 feet deep above a hard slate and serpentine bedrock. The dredge was digging about 2000 cubic yards in 24 hours in July 1941. Fifteen men were employed under Oscar Bahrenburg, dredgemaster. This dredge was dismantled for shipment to Alaska early in 1942.

Farnsworth hydraulic mine on the South Fork of Salmon River in the Cecilville district includes two association placer claims of 160 acres each, and two 20-acre placer claims. It is owned by Edward McBroom of Cecilville. Water is obtained from the South Fork of Salmon River through 5 miles of ditch. It is delivered to a giant with a 6-inch nozzle under a 120-foot head. The bank is about 40 feet high with 6 to 8 feet of gravel above a gray andesite bedrock. Gold is recovered in three lengths of sluice boxes 3 feet wide with railroad-iron riffles. McBroom and Kenneth Kinsman operated the property as partners in the 1947 season.

Fort Goff hydraulic mine in sec. 31, T. 47 N., R. 12 W., M. D., includes 80 acres of patented land on the north bank of the Klamath River, owned by Frank Schulmeyer. The property has been idle for many years but J. W. Welch of Seiad had five men employed in February 1947 repairing the $1\frac{1}{2}$ miles of ditch and flume from Fort Goff Creek preparing to operate. (Irelan 88, p. 596; Crawford 94, p. 282; 96, p. 401; Brown 16, p. 850; Averill 35, p. 319.)

French Gulch Gold Dredging Company, 2404 Russ Building, San Francisco, closed their operation on Clear Creek in Shasta County in July 1946 and moved the dredge and equipment to Indian Creek in Siskiyou County near Fort Jones on land situated in secs. 13 and 14, T. 44 N., R. 9 W., M. D., owned by George Milne of Fort Jones. The bucket-ladder dredge was built by the Washington Iron Works of Seattle in 1940. It has a pontoon-type hull 90 by 40 feet and 7 feet deep. The 85-foot digging ladder carries 75 buckets of $4\frac{1}{2}$ cubic feet capacity. The trommel is 5 feet in diameter and has a 21-foot length of slotted screen with three-eighths inch holes spaced at $1\frac{1}{2}$- and 1-inch intervals. There are eight 30-inch sluices 10 feet long feeding two 30-inch downstream sluices fitted with rubber Hungarian riffles on each side. Two Bingham centrifugal pumps, an 8-inch and a 10-inch, supply the water. All equipment is operated by electric motors. The gravel is about 18 feet deep on Indian Creek. Etheredge Walker, 2404 Russ Building, San Francisco, is president of the company; Ed Shuford is dredgemaster at Indian Creek. Eighteen men are employed.

Gibralter mine, 81 acres of patented ground in sec. 13, T. 43 N., R. 10 W., M. D., is owned by the C. E. Jacobsen Estate, Greenville. A quartz vein 18 to 42 inches wide strikes N. 5° E. and dips 34° E. It is developed by an incline shaft on the vein for a depth of 100 feet. At 90 feet depth, a drift was run north on the vein for 60 feet, and a raise was run up 18 feet above the drift at 20 feet north of the shaft. The vein was about 20 inches wide and is said to have yielded 35 tons of ore assaying $28.50 per ton in gold. The property was equipped with a single drum hoist geared to a four-cylinder gasoline engine. Compressed air was delivered by a Schram 7- by 9-inch compressor driven by a Sterling gasoline engine.

The mill was equipped with an ore bin topped with a bar grizzly spaced at $1\frac{1}{4}$ inches; a Challenge ore feeder; Pacific Iron Works five-stamp mill with a 10-mesh screen; and a 4- by 12-inch copper lip plate followed by a 4- by 4-foot copper amalgamating plate. The tailing was ground to 50-mesh in a Straub ball mill and treated in a Gibson impact amalgamator. The tailing from the amalgamator was treated in four Denver flotation cells and finally on a Deister table. A Dorr rake classifier was cut out of the circuit. The laboratory was equipped with a Braun "chipmunk" crusher and a Braun disc pulverizer. All mill equipment was driven by electric motors. Water was pumped from a shaft in the valley by a Fairbanks-Morse centrifugal pump through 600 feet of 2-inch line against a 125-foot head. The pump was driven by a $7\frac{1}{2}$-horsepower electric motor. This property has been idle since May 1941.

Gold Bar mine includes 12 unpatented claims about a mile north of Hawkinsville in sec. 2, T. 45 N., R. 7 W., M. D. It is owned by D. G. Thompson of Yreka. Quartz stringers and narrow veins in meta-andesite have been developed by four shafts up to 50 feet in depth, five adits up to 140 feet in length, and numerous shallow pits and trenches. Thompson claimed that composite samples of the meta-andesite in zones including quartz stringers, indicate that an average of $4 to $5 per ton in gold can be mined from a large area on the surface. The property is equipped with a Chicago pneumatic portable air compressor, a mounted rock drill, rubber-tired wheel barrow, and small tools. It was idle when visited in March 1947.

Gold Mountain group includes 29 claims in sec. 2, T. 41 N., R. 7 W., and sec. 35, T. 42 N., R. 7 W., M. D., owned by James and Agnes Furlong of San Francisco and Arvil V. Miner of Richmond. Numerous outcrops of quartz, quartz diorite porphyry, and quartzite occur near the contact of Paleozoic sediments with serpentine and diorite. In some places they carry considerable pyrite and some pyrrhotite. They have been prospected by numerous cuts and trenches and two adits. The north adit was run in a S. 47° W. direction for about 235 feet through diorite containing pyrite and some pyrrhotite. It was said to assay from $1 to $2 per ton in gold and to show a trace of nickel.

The east adit was driven S. 15° E. for 215 feet in quartz diorite which bore considerable pyrite. There are several zones of quartzite in which are seams of white quartz striking east. One zone 40 feet wide outcrops 15 feet above the ground and strikes S. 60° E. The southwest adit was run N. 20° W. for 90 feet through gray quartz diorite having seams of red iron oxide. This material was said to assay from $2 to $7 per ton in gold. The south adit, said to have been started in 1876, was driven in a northwesterly direction for some 500 feet through a pyrite-bearing gray quartz diorite with narrow quartz seams. No assays were reported from this adit. The claims have been idle except for assessment work in recent years. Mapping and sampling might disclose zones where low-grade gold ores could be mined profitably.

Gold Reef mine includes 280 acres of patented land in sec. 34, T. 43 N., R. 10 W., M. D., owned by the John F. Lewis Estate, Fort Jones. It was leased to Philip Suetter of Portland in 1941-42 with an option to purchase. A crosscut run S. 83° W. for 215 feet cut 25 feet of pyrite near the face which assayed $2 per ton in gold but contained no copper. About 85 feet above the crosscut, a leached white sugary quartz, stained yellow, brown, and black in streaks, outcrops for a width of about 21 feet for a length of about 500 feet in a S. 25° W. direction. It was said to assay $4.50 per ton in gold. Both walls are meta-andesite. The outcrop was stripped of 15 feet of overburden with an International T-D9 bulldozer. Vertical holes were drilled 5 feet deep, spaced at about 3-foot intervals, and blasted to make a trench 15 feet wide. The ore was loaded into mine cars with a link-belt ''Speedster L-S40'' shovel, and hauled to a 20-ton bin by a Ford model ''A'' powered locomotive. It was crushed to minus 2-inch size in a 20-inch gyratory crusher. A three-rail, 24-inch gauge tramline, built of 24-pound rails on a 32 percent grade for a length of 1420 feet had two three-fourths-ton cars which dumped automatically into the 20-ton mill ore bin. Ore was crushed to 40-mesh in two ''Clyde Smith'' ball mills and was treated in two Cascade amalgamators and on five Wilfley tables. An experimental 20-ton copper smelter was purchased to treat the concentrates. The mill treated 30 tons per day for about 3 months in 1942, then all operations were shut down. This property was fully and completely equipped and was provided with bunk and boarding houses, offices, laboratories, electric-light plant, and water system. It has since been dismantled.

Gold Ventures Ltd., Paul A. Bundy, president and general manager, Box 323, Grass Valley, California, have a lease with an option to purchase on the Portuguese placer mine in sec. 4, T. 46 N., R. 12 W., and sec. 32, T. 47 N., R. 12 W., M. D., from Stanly Davis of San Francisco, California. They are assembling a dragline dredge on the property. Equipment includes a Lima dragline with a 70-foot boom and a 3-cubic-

yard bucket. It is powered by a Cummins 250-horsepower diesel engine. The Bodinson washing plant has five steel pontoons making a hull 36 by 48 feet and 54 inches deep. The trommel is 60 inches in diameter and 39 feet long, with 25 feet of half-inch holes. The stacker belt is 36 inches wide and 70 feet long between pulleys. There are 10 side sluices 30 inches wide and two downstream sluices 30 inches wide fitted with Hungarian riffles on each side. Water will be furnished by a 10- and a 4-inch United Iron Works centrifugal pump. Power will be supplied by a 200-horsepower Murphy diesel-electric motor and each piece of equipment will have a separate motor drive. There is an International T-D-18 bulldozer for clearing the land, and a Rowe 300-ampere arc welder to make necessary repairs to steel equipment. Ten men were employed May 28, 1947 under John Frasher. This dredge was moved from Bridgeport and was formerly known as the Sunmar dredge.

Golden Eagle mine is on patented land in sec. 11, T. 44 N., R. 9 W., M.D., owned by George Milne of Fort Jones. It has had an estimated production of $1,000,000 but has been idle since 1931. (Irelan 88, p. 625; Crawford 94, p. 282; Logan 25, p. 440; Averill 31, p. 35; 35, pp. 283, 319.)

Golden Rule mine includes three quartz claims and a mill site on the North Fork of Hungry Creek in sec. 26, T. 48 N., R. 8 W., M.D. It is owned by Robert Claye Jr. of Yreka, who purchased it from R. T. Baldwin in 1938. An 8- to 10-inch quartz vein in granodiorite strikes S. 85° E. and dips 87° N. It is developed by a 4- to 6-foot shaft 20 feet deep and a drift run S. 85° E. for 20 feet. There is a single-drum hoist with a Fairbanks-Morse gasoline engine to hoist a bucket made from a gasoline drum. An old shaft 65 feet deep was filled with waste rock from the new shaft. An adit whose portal is about 80 feet east of the shaft and 90 feet lower, was driven about 300 feet with 100 feet of drift on the vein. The ore was milled in a 5-ton Chilean mill, belt driven by a 4-horsepower gasoline engine, and the gold was recovered by amalgamation and concentration on an Ellis table. Some pyrite and chalcopyrite is associated with the quartz. Robert Claye and his son work alone at this property. (Averill 35, pp. 261, 319.)

Golden Wonder group of six quartz and two placer claims in Timber Gulch, in secs. 27, 28, and 34, T. 45 N., R. 8 W., M.D., is owned by Fred Talbott. This property has been idle except for occasional small-scale ground sluicing by Talbott. Water is obtained from a reservoir through 300 feet of 6-inch pipe, and is delivered to a giant with a 2-inch nozzle under a 50-foot head.

Hansen group, includes the Hansen, Gilta, Gold Run, and Knownothing claims on Knownothing Creek in secs. 1 and 12, T. 9 N., R. 7 E. It is owned by Bessie M. Hansen and Marian Justus of Forks of Salmon. Norman Marvin of Etna is reported to have recovered 100 ounces of gold from 30 tons of sorted ore on this property in 1946. (Dunn 93, p. 446; Crawford 94, p. 284; 96, p. 404; Logan 25, p. 442; Averill 35, p. 285.)

Hegler (Oregon) mine includes a group of claims in Lawson Gulch in sec. 3, T. 45 N., R. 8 W., M.D., owned by H. L. Heinrichsen and Nick G. Kapranos of Yreka. It was leased in 1947 to Max Erwin of Yreka who had three men employed reopening an old adit that was caved near the portal. The property was last worked in 1917 and is said to have a vein 2 to 6 feet wide that averaged $5 a ton in free gold. (Dunn 93, p. 446; Crawford 94, p. 284; 96, p. 405; Logan 25, p. 453; Averill 35, p. 325.)

Hogan mine is a group of six claims in sec. 32, T. 41 N., R. 10 W., M.D., owned by George Baker of Etna. A quartz vein 6 to 12 inches wide with granodiorite walls strikes S. 20° E. and dips 28° E. It is developed by several short adits and surface cuts. A portion of the vein has been stoped to the surface. There is a one-stamp mill equipped with two 30- by 48-inch copper amalgamating plates and an 8-inch sluice box 6 feet long fitted with expanded metal over burlap. The mill can be run by 36-inch Pelton water wheel when there is sufficient water, and it has a one-cylinder Novo gas engine as auxiliary power. Baker said he purchased this property from James O'Connell in 1935 and he has been working alone, mining and milling about 25 tons per year. (Averill 35, pp. 302, 321.)

Homestead placer claim, located in sec. 2, T. 40 N., R. 9 W., M.D., is owned by A. E. Hughes of Etna. The gravel is from 2 to 8 feet deep above andesite and serpentine bedrock. Water is brought from Sugar Creek through 9 miles of ditch and about 300 feet of 6- and 7-inch pipe to a giant, under a 50-foot head. A ''self shooter'' installed in a 24- by 24-inch flume 30 feet long is used when water is low. Gold is recovered in 60 feet of bedrock race and 32 feet of sluice boxes 24 inches wide and 12 inches deep. Hughes and George Cory operate the property as partners.

Horton Gulch. A group of 200 acres held by location, and the adjoining Mount Shasta Mining Company property of 131 acres of patented land, in secs. 29 and 30, T. 38 N., R. 11 W., M.D., are owned by John D. and Ada McBroom of Cecilville. Portions of these properties were worked by hydraulic mining, but they have been idle in recent years. They were leased to William I. Zoch in 1945 and were being considered for possible dredging. (Averill 46, p. 294.)

Humming Bug Mine, Inc., C. S. Haley, president, owns 620 acres of land in sec. 17, T. 45 N., R. 7 W., M.D. A $3\frac{1}{2}$-foot quartz vein carrying gold is developed by a 700-foot adit. The property has been idle since 1939 when fire destroyed the compressor, drill sharpener, and several rock drills. Much of the machinery for the 40-ton flotation mill has been sold and removed.

Ida May mine, in sec. 15, T. 39 N., R. 11 W., M.D., was last operated by the Norcal Mining Company in 1938. The Ida May, Francis Bell, and Lucky Strike claims have since been purchased from the Norcal Company by John W. Usher of Sawyers Bar. Usher has been sluicing the Ida May dump through 40 feet of 12- by 12-inch sluice boxes fitted with metal-lath riffles. Water is obtained from Eddy Creek. He has combined the three Ida May claims with four adjoining claims to form the *Security Mines group.* (Tucker 22, p. 297; 23, p. 11; Logan 25, p. 445; Averill 35, pp. 301, 321.)

Indian Bottoms Mining Company, 356 South Mission Road, Los Angeles, California, owns four claims and leases one claim on the north bank of the Salmon River in secs. 16, 20, and 21, T. 11 N., R. 7 E., H. An old river channel some 40 feet higher than the present river has a bank about 40 feet high, including a gravel bed about 7 feet thick above granite bedrock. Water is obtained from Portuguese Creek and delivered under a head of 126 feet to two No. 4 giants fitted with 6-inch nozzles. Gold is recovered in 360 feet of 30- by 30-inch sluice boxes fitted with steel rails for the first 24 feet, and then with 9-inch block riffles. The boxes drop 8 inches in 12 feet. A derrick for handling boulders has a mast 86 feet high and a boom 90 feet long. It is equipped with a 65-horsepower Cater-

pillar diesel engine. A Palmer 25-kilowatt generator driven by 75-horsepower International diesel engine provides electricity for the flood lights and camp buildings. Six men were employed on each of two shifts in September 1941. This property is now idle.

Joubert placer includes 90 acres of land 2 miles south of Sawyers Bar in secs. 4, 8, and 9, T. 39 N., R. 11 W., M.D., owned by L. J. Joubert of Sawyers Bar. From 1938-46, three hydraulic pits on this property were leased to Stanley Czerwinski, who had 7 men employed. Water was obtained from Eddys Gulch through about 4000 feet of flume and ditch. A small reservoir above the pits supplied water under a 180-foot head to two giants with 4-inch and 3-inch nozzles respectively.There are about 30 feet of loose gravel with 20 feet of overburden above a hard slate bedrock. About 600 feet of 18- by 30-inch sluice boxes sloping 6 inches to 12 feet are fitted with block riffles.

In 1947 the property was leased to Alex Markon and his stepsons, Gene and Melvin Cramer. They were directing water from a 3-inch nozzle against a bank 50 feet high including about 30 feet of loose gravel above a hard blue slate bedrock. They had 72 feet of sluice boxes 16 by 16 inches with a slope of 8 inches to 12 feet. Of 33.78 ounces of gold recovered, only 10 ounces could be screened through a 10-mesh screen, so they were installing an undercurrent to trap any finer gold that might be present. The Joubert placer was first operated in 1855 and it is described in earlier reports of the State Division of Mines. (Logan 25, p. 474; Averill 46, p. 294.)

Judge hydraulic mine includes six unpatented claims in sec. 33, T. 40 N., R. 11 W., M.D., owned by J. F. and Patricia Judge of Santa Monica, California. It is leased to a copartnership including H. D. Winship, Vernon Allen, and E. A. Von Gerlitz. About 1½ miles of ditch provides water under a 200-foot head from Eddys Gulch. In March 1947 two men were employed using a No. 2 giant with a 4-inch nozzle. The bank was about 100 feet high including loose red soil and 50 feet of gravel above a hard slate bedrock. There are about 500 feet of 2- by 2-foot sluice boxes lined with rail and block riffles. A derrick for handling boulders has a 70-foot mast and is powered with a single-drum hoist geared to a 1-cylinder gasoline engine. The bank is said to run from 35 cents to $1 per cubic yard.

Kanaka Hill hydraulic mine includes eight 20-acre claims on the east bank of the Klamath River in secs. 27, 28, and 34, T. 16 N., R. 7 E., H., owned by Steve S. Green of Happy Camp. Two old river terraces 50 and 185 feet above the present river are estimated to contain 1,200,000 yards of gravel above a greenstone-schist bedrock that will average 20 cents per cubic yard in gold. Water is available from Kanaka Creek through two ditches delivering water to either the upper or lower gravel under 140 feet of head. Additional water can be obtained from Wilson and Buzzard Creeks by digging the necessary ditches. The property has not been operated for several years, and the ditches, pipe lines, and sluice boxes will need some repairs. (Averill 35, pp. 290, 321.)

K. C. mine includes 10 mining claims, one of which is patented, in sec. 6, T. 45 N., R. 9 W., and all of sec. 1, T. 45 N., R. 10 W., M.D., except Lot 1, owned by Florence M. Cooper, Yreka. It is leased with an option to purchase by A. L. Damon, president of the Thompson Divide Mining Company. A quartz vein 8 to 48 inches wide strikes S. 30° to 70° W. and dips 18° to 33° N. The quartz is stained brown and is in bands from 1½

to 4 inches wide separated by thin layers of black broken shale with light-brown clay seams. The property is developed by five adits from 80 to 400 feet long, three of which are caved and inaccessible, by short raises on the vein, and by open cuts on the vein. The vein in No. 2 adit is said to have been 2.2 feet wide and to have averaged $18.75 per ton in free gold. Both walls are black shale. A new mill building has been built at the camp site from lumber sawed on the property. Dump trucks will haul the ore $1\frac{1}{4}$ miles down hill to the mill and discharge over a rail grizzly with three-fourths-inch spaces and sloping 45°. The undersize will fall into the fine-ore bin. Oversize will be crushed to half an inch in a 6- by 8-inch jaw crusher, and discharged into the fine-ore bin. The fine-ore bin has two chutes from which the ore is drawn by disc feeders to feed a 2- and a 5-stamp battery. The stamps weigh 1250 pounds and will drop 6 inches, 100 times per minute. The ore will be crushed to minus 40-mesh and amalgamated on copper plates. The tailing will be concentrated on a Wilfley table. It is expected that 25 tons in 24 hours will be milled. Water is obtained by gravity from a spring and delivered through 1000 feet of 2-inch pipe to a 1200-gallon-capacity galvanized-iron tank. Power will be obtained from a diesel engine which has not yet been delivered. There are five cabins including a boarding house at the camp. Seven men and a cook were employed May 28, 1947 under Tom Clark, superintendent. (Averill 31, p. 35; 35, p. 321.)

Katie May group of five claims in secs. 13 and 24, T. 45 N., R. 8 W., M.D., is owned by A. S. and Frances E. Calkins. Quartz stringers and narrow veins 4 to 14 inches wide occur in greenstone near a contact with black shale. They have been prospected by numerous surface cuts, several short adits and shallow shafts, most of which are now caved. Averill (35, p. 291) quotes a former lessee as saying that $70,000 was produced from a 10-inch vein in a stope 40 feet long. In October 1945, A. O. Witte of Redding, California, leased and prospected this property, but no operation ensued. (Crawford 96, p. 409; Brown 16, p. 836; Logan 25, p. 448; Averill 35, pp. 291, 308, 321.)

Keenan mine comprises 40 acres of patented land in the NE$\frac{1}{4}$ sec. 7, T. 43 N., R. 9 W., M.D., and one unpatented claim in sec. 12, T. 43 N., R. 10 W., M.D., owned by Arthur Keenan, Fort Jones. A quartz vein $3\frac{1}{2}$ feet wide strikes N. 10° E. and dips 45° E. It is developed by a shaft 111 feet deep on the vein, and a crosscut to the vein from a point 100 feet south and 50 feet lower. A second adit, 175 feet lower than the collar of the shaft and 300 feet south was driven 300 feet to a fault striking N. 60° E. and dipping steeply southeast. Seventy feet of drifting along the fault did not pick up the vein. The mine is idle and the shaft is almost full of water.

King Solomon mine on Mathews Creek in sec 14, T. 38 N., R. 12 W., M.D., includes 12 claims owned by George Milne of Fort Jones. It was last operated by the King Solomon Mines Company in October 1940. Machinery and equipment have since been removed. The mill tailing was reworked by William George of Sawyers Bar and Virgil Gray of Cecilville in 1945 and 1946. Water from Mathews Creek was diverted against the tailing to wash it into about 120 feet of sluice boxes fitted with Hungarian riffles. Coarse material was screened out at the first box. Water from a fire hose fitted with a $1\frac{1}{4}$-inch nozzle helped to move the material. The mill tailing has been practically all cleaned up. (Jenkins 35, p. 159; Averill 35, p. 321.)

Klamath River dredge was operated by the Wm. von der Hellen Mining Company, Box 1026, Medford, Oregon. The company owns a strip of land 400 feet wide along the Klamath River in sec. 16, T. 46 N., R. 7 W., M.D. Operations started in July 1940 with new equipment including a three-winch Monighan dragline with an 80-foot boom, and a $2\frac{1}{2}$-cubic-yard bucket. It had a Fairbanks diesel engine rated at 190 horsepower. The washing plant was built by Hickinboatham Brothers of Stockton and had six steel pontoons, making a barge 48 by 36 feet; and a trommel 64 inches in diameter, 35 feet long, with 24 feet of three-eighths- to five-eighths-inch holes. The stacker belt was 36 inches wide and 70 feet long. Water was supplied by a United Iron Works 10-inch centrifugal pump. Gold was recovered in sluice boxes fitted with steel Hungarian riffles. Power was furnished by a Caterpillar D-13000 engine. The gravel was 28 feet deep above a hard bedrock and a crew of 12 men was digging 2500 cubic yards in three shifts. Sands were treated in a cleanup barrel 30 inches in diameter by $3\frac{1}{2}$ feet long, by rotating 300 pounds of sands and 2 pounds of mercury with eight 6-inch manganese-steel blocks to polish the gold. The dredge was shut down September 27, 1942, and much of the equipment moved to war industries. It has not been operated since.

Last Chance mine consists of three claims in the SE$\frac{1}{4}$ sec. 23, T. 48 N., R. 8 W., M.D., owned and operated by a co-partnership composed of Stuart Cosgrave, A. A. Carlson, and John Krallman, Box 624, Yreka. The property was purchased in 1945 from Gus and George Avergis, who had sunk a vertical shaft 18 feet deep on a 20-inch quartz vein striking N. 87° W. in granodiorite. The new owners sank a new shaft about 15 feet east on a 45° E. incline 80 feet deep, but did not find the vein until they cross-cut west for 18 feet at a depth of 60 feet. The quartz was only $2\frac{1}{2}$ inches wide at this depth, but it was said to assay $152 per ton. A single-drum Smith and Western hoist driven by a Milwaukee air-cooled gasoline engine pulls a mine-car skip up the shaft to dump into a wooden bin. An Ingersoll Rand compressor, belt-driven by a Star automobile engine provides compressed air for drilling. Mill equipment includes a 10- by 14-inch jaw crusher, belt-driven by an old automobile engine; a 50-ton-capacity Hardinge ball mill, belt-driven by G.M.C. engine; a Dorr double-rake classifier; and a five-plate cascade amalgamator. The ball mill and classifier were not used and the cascade amalgamator was to be replaced by a 5-ton Huntington mill. Water is obtained from a spring and flows through a 1-inch pipeline to a 12- by 16- by 6-foot concrete tank. Three frame cabins, a bunkhouse, boardinghouse, and tents are provided for the employees. The property was idle when visited in August 1946.

Lincoln Gold Dredging Company, a partnership of E. M. (Bing) Clark, Redding, California, and W. K. Jansen, Lincoln, California, operated a dragline dredge on Greenhorn Creek about 2 miles west of Highway 99 in sec. 29, T. 45 N., R. 7 W., M.D. The equipment was moved from the Trinity River near Lewiston and started operating at this location July 10, 1941. It included a P & H dragline with a 60-foot boom using a $1\frac{3}{4}$-cubic-yard bucket and powered by a D-13000 Caterpillar engine. The washing plant was built on five steel pontoons, 8 by 30 by 3 feet, making a hull 40 by 30 feet. The trommel was 54 inches in diameter and 28 feet long with 18 feet of three-eighths- to $1\frac{1}{2}$-inch holes. The stacker belt was 36 inches wide and 50 feet long. Power was obtained from a D-13000 Caterpillar engine, and a General Electric generator supplied current for lights. The sluice boxes were 28 inches wide and there were eight cross

sluices and three downstream sluices on each side. The cross sluices were fitted with Hungarian riffles and the downstream sluices had expanded metal over cocoa matting, and a 12- by 28-inch copper amalgamating plate under the expanded metal in each sluice. Water was pumped by a 6-inch centrifugal pump driven by a D4 Caterpillar engine. The gravel was 16 feet deep over a fairly hard slate bedrock. In July 1941 the operators were digging about 2000 yards of gravel in 24 hours, which yielded about 18 cents per cubic yard.

Three men were employed on each of three shifts, and an extra man on day shift to operate the D6 Caterpillar bulldozer clearing the brush and overburden from the gravel. E. M. Clark was in charge of operations.

Long Gulch mine in sec 8, T. 45 N., R. 7 W., M.D., includes the Gold Leaf, Beauty, and Prairie claims owned by Paul and Harry C. Dobyns, 227 Pine Street, Yreka, California. It is leased, with an option to purchase, by a co-partnership composed of A. N. Whealdon, E. L. McNaughton, G. Ankeney, and H. F. Lintner of Redding. A quartz vein averaging about 3 feet in width has been developed by three adits. The lowest adit is about 450 feet long, 350 feet of which is a drift on a vein 2 to 3½ feet wide striking S. 35° W. to S. 72° W., and dipping 45° to 67° NW. At about 160 feet from the portal, a 40-foot raise on the vein holed to surface, and at 430 feet a second raise was run to connect with the adit level 70 feet above. It holed into the adit about 20 feet from the face. The vein averaged 30 inches in width in the raise except where faulted 16 feet to the south. The adit 70 feet higher drifted 176 feet on the vein, and a third adit 300 feet higher has a drift 55 feet long on the vein and a 40-foot raise to surface. The ore from this upper adit was milled in an 8-foot arrastra in 1914, but the recovery is not known. Recent mill tests show that there is little free gold.

The vein is white quartz with fine, sharp, pyrite cubes and occasionally some galena. The walls are greenstone with thin seams of quartz parallel to the vein, and include many fine, bright cubes of pyrite. The vein has been faulted to the south for a maximum distance of 16 feet in three places by faults striking S. 70° to 80° W. and dipping 22° to 30° S. Equipment includes a Gardner compressor driven by a four-cylinder Ford engine; a mounted rock drill; mine car, and accessory small tools. Two men are employed drifting and raising on the vein to block out sufficient ore to justify building a mill. (Crawford 96, p. 413.)

Lucky Boy mine in sec. 33, T. 17 N., R. 8 E., H., includes seven unpatented claims owned by Harry Sibley, J. W. Stanton, and Martin Jolly of Happy Camp, California. A belt of tan-colored pyritic schist with numerous quartz stringers and some narrow quartz veins has been prospected by numerous surface cuts and short adits. Twenty-three samples are said to have averaged $4.71 per ton in gold. Ore from a stope on the Lady Luck claim 100 feet long and 10 feet wide is said to average $10 per ton in gold. Another adit is said to have 4 feet of ore assaying $5.75 per ton in gold and 2½ percent copper. There is a two-room cabin on this property. No work, except prospecting has been done in recent years.

Lumgrey mine, consists of eight claims in sec. 22, T. 47 N., R. 8 W., M.D., owned by H. H. Lotz, Klamath River Post Office. A zone of quartz stringers in a granodiorite schist is said to average $5.20 per ton in gold. From 1700 tons of ore milled in 1939 in a 10-stamp mill, a 34 percent recovery by amalgamation is reported. The property is idle except for assessment work. (Averill 35, pp. 261, 322.)

Mammon group includes 17 claims in sec. 14, T. 41 N., R. 7 W., M. D., owned by James and Agnes Furlong of San Francisco and Arvil V. Miner of Richmond. Numerous outcrops of copper-stained quartz and quartz porphyry dikes occur on these claims. They are near the contact of granodiorite with shale. On the Mammon No. 4 claim, a northward-trending 18-inch quartz vein carrying some chalcopyrite is said to assay \$7 per ton in gold. It was prospected by a pit 4 by 6 feet and 6 feet deep. An adit 150 feet long at a lower elevation did not reach the vein.

On Mammon No. 9, a prospect crosscut was driven S. 55° E. for 550 feet, but no vein was encountered. On Mammon No. 1, a quartz porphyry dike at the "Barrundon" cut strikes S. 65° E. and dips 64° S., and is said to assay \$5.40 per ton in gold for a width of 21 feet. A 6- by 10-foot shaft 9 feet deep was sunk on a 4-foot vein striking S. 25° W. and dipping 55° to 90° E. This vein was said to assay $3\frac{1}{2}$ percent copper and \$33 per ton in gold. The country rock is granodiorite.

On Mammon No. 11, a shaft 18 feet deep was filled with water and inaccessible; quartz examined on the dump was stained with copper minerals. Ore from a trench 300 feet long is said to have averaged $1\frac{1}{2}$ percent copper and 50 cents per ton in gold. A quartz porphyry dike about 200 feet wide, which strikes northwest for some 2000 feet, is said to assay from \$2 to \$8 per ton in gold. These claims have been idle in recent years except for assessment work.

Marath Mining Corporation included 120 acres of patented land in SE$\frac{1}{4}$ sec. 7, T. 46 N., R. 6 W., M. D., owned by Varil S. Nimes and wife, Box 25, Hornbrook. An andesite dike 35 feet wide, having numerous quartz stringers, strikes northward between black slate walls, and dips vertically. It is developed by a crosscut west, 150 feet long to the dike, a drift south 100 feet long in the center of the dike, and a drift north along the east wall for 60 feet. A 75-foot vertical raise connects with a second adit 35 feet long. Nimes and his wife milled the ore from these developments by crushing with a 4- by 5-inch jaw crusher, followed by an 18-inch by 4-foot-diameter ball mill, and concentrating with a Draper jig.

In 1946 the property was leased, with an option to purchase, to John M. and George Carras, a partnership, who formed the Mareth Mining Company with Carl Yates of Yreka as manager. Roads were built to the dike with a bulldozer, and a mill was built. Trucks were dumped over a grizzly with rails spaced at 8 inches, into a steel cylindrical ore bin 9 feet in diameter and 24 feet high. Material over $1\frac{1}{2}$-inches in size was crushed in a 9- by 16-inch jaw crusher driven by a "Jeep" motor operated on Butane fuel; it was then delivered to a second steel cylindrical fine-ore bin, 9 feet in diameter and 24 feet high, by a 14-inch belt conveyor 90 feet long inclined 10 percent above the horizontal. Material from the fine-ore bin was fed to a 3- by 4-foot Straub ball mill driven by 5 "V" belts from a "Jeep" engine. A 40-mesh screen-wheel classifier returned oversize to the ball mill and the fines to a Draper jig. Jig tailing was run over a 2- by 10-foot corduroy table. Concentrate was treated in an arrastre-type amalgamator. Mill heads were said to average from \$6 to \$7 per ton and tailing assayed 90 cents to \$1.20 per ton. About 300 tons were milled between August 30 and November 15, 1946, when the property was shut down. The mill capacity was too small for this low-grade ore. Two men were employed at the mine and three

men at the mill, on one shift. Mining equipment remaining at the property includes a Caterpillar bulldozer; a 10- by 10-inch Ingersoll-Rand compressor; an S-49 Ingersoll jackhammer with shell and column; a supply of 1-inch hexagonal drill steel and Timken bits; two mine cars; rails, picks, shovels, and hand tools sufficient to resume mining on a small scale.

Mattoon mine, in sec. 34, T. 45 N., R. 9 W., M. D., was operated by Amox Ginn of Fort Jones with a crew of four men in May 1937. Gravel was dug by a power shovel with a three-fourths-cubic-yard bucket, loaded onto trucks of $1\frac{1}{2}$-cubic-yard capacity, and hauled to a washing plant consisting of a trommel, sluices, and belt tailing stacker. The plant was said to have had a capacity of 250 yards in an 8-hour shift. The property is idle. (Averill 31, p. 60; 35, p. 323.)

Mayland Mining Company is described under the White Bear Mine.

Middle Fork Mines. A. O. Witte of Redding has leased, with an option to purchase, two quartz claims owned by Everett Crouch, and four adjoining quartz claims owned by Lowell Hall on the Middle Fork of Humbug Creek in sec. 11, T. 45 N., R. 8 W., M. D. Quartz stringers and narrow veins occur in a soft medium-grained granodiorite near a contact with fine-grained hornblende diorite. The quartz stringers have been crushed and broken. They are commonly stained yellow and brown with limonite, and occasionly stained black with manganese. The Hall claims have been prospected by numerous shallow pits and short adits. On the Crouch claims, a caved adit is said to be 120 feet long with an 80-foot vertical raise to the surface on a vein 12 to 36 inches wide with granite walls. An old trestle from the adit and a small mill with a 3- by 4-foot ball mill are in a wrecked condition.

Witte has built a small mill on the Hall claims consisting of a 30-inch square hopper with a steel-rod grizzly spaced at 1 inch. Undersize drops through about 12 feet of 12-inch-diameter steel pipe to a 5- by 7-foot fine-ore bin 8 feet deep. The ore is fed by a disc feeder to a Huntington mill 5 feet in diameter and 30 inches deep, and ground through 35-mesh slotted screens. The crushed ore is run through a five-pan cascade-type amalgamator with 20-inch square pans fitted with 5- by 20-inch copper plates, and having one-eighth-inch holes for the pulp to drop through from pan to pan. The tailing is run through 20 feet of sluice boxes 10 inches wide and $2\frac{1}{2}$ inches deep, lined with corduroy. Power is supplied by a De Soto automobile engine. One man is employed.

Midland Company, Inc., a partnership of Fred Hoyer and Elmer Dick of Sawyers Bar, commenced operating a dragline dredge on the North Fork of Salmon River 3 miles west of Sawyers Bar in November 1940. They had leases on 4 miles of land along the river. Equipment included a Lorain dragline with 55-foot boom, and a $1\frac{1}{2}$-cubic-yard bucket powered by a Caterpillar D-13000 engine. The washing plant was floated on four 10- by 30- by $3\frac{1}{2}$-foot wooden pontoons. The trommel was 4 by 30 feet and had 23 feet of three-eighths- to one-half-inch holes. The stacker belt was 28 inches wide and 45 feet long. The sluice boxes were 48 inches wide and there were three cross sluices and two downstream sluices on one side, and six cross sluices and two downstream sluices on the other side. They were fitted with expanded metal over cocoa matting. Power was furnished by an 85-horsepower Fairbanks-Morse diesel engine with a 1500-watt generator for electric lights. The gravel was 12 feet

deep above a hard serpentine bedrock. There were many medium-size boulders. About 1600 cubic yards of gravel was dug in two shifts. Nine men were employed.

The dredge has been fitted with a single steel bucket about 6 feet wide with a 6- by 30-foot metal slide attached on the back end. It is designed to be lowered between two pontoons for digging, and then elevated by steel ropes through sheaves mounted on steel frame towers rising above the pontoons. The rock will slide into the hopper of the washing plant when the bucket is elevated. This design was never operated because the war closed gold-mining operations. It stands idle on the river about a mile below Sawyers Bar. A. C. Crawford is in charge.

Moccasin mine is owned by Larsen Brothers and Harms Brothers, Route 4, Box 2220, Sacramento, California. Dredging started in January 1940 on a strip of land half a mile wide and 2 miles long on the Klamath River near Horse Creek, in secs. 14 and 15, T. 46 N., R. 10 W., M. D. Equipment included a Bucyrus-Monighan Model-5W, Walker-type dragline with a 100-foot boom and a 4½-cubic-yard bucket. Power was furnished by a 250-horsepower Fairbanks-Morse diesel engine. The Bodinson-built washing plant had eight steel pontoons making a barge 48 by 64 feet. The trommel is 6 feet in diameter and 47 feet long, with 30 feet of three-eighths- to three-fourths-inch holes. Water was supplied by a 14-inch United Iron Works centrifugal pump driven by a 100-horsepower General Electric motor, and a Sterling 4-inch centrifugal pump driven by a Wisconsin gasoline engine. The 42-inch stacker belt was 85 feet long. Power was furnished by a 300-horsepower Fairbanks-Morse diesel engine which drove a 200-kilavolt-amperes Fairbanks-Morse generator. There were 12 sluice boxes 29 inches wide feeding three downstream sluice boxes 29 inches wide on each side of the barge. They were fitted with Hungarian riffles and rubber mercury traps. The gravel was 25 to 45 feet deep above a soft schist bedrock. The operators were digging 6000 cubic yards in 24 hours in July 1941. Overburden was removed with a LeTourneau 12-cubic-yard carryall drawn by a D-8 Caterpillar tractor. A camp consisting of eight two-room cottages was built for employees about 3 miles above Horse Creek. This dredge was shut down June 25, 1946, and moved to Happy Camp in August, when it was renamed Scandia No. 2 dredge.

Mount Vernon Mines, Inc., comprises 70 acres of patented, and 40 acres of unpatented land in sec. 26, T. 45 N., R. 8 W., M. D. Kenneth K. Ash, Box 916, Yreka, is president and general manager. In October 1945, a horizontal diamond-drill hole was started in a S. 28° W. direction in the face of No. 6 adit. At 500 feet the hole turned downward 7 degrees and continued on that slope to bottom at 2084 feet. Between the depths of 39 feet 10 inches and 52 feet, the core was reported to assay $14 per ton in gold. The hole was run through greenstone, which showed pyrite and numerous thin seams of quartz in many cores. It was sampled and assayed at 5-foot intervals and is said to have cut quartz veins 32 inches wide assaying $4 per ton at 1150 feet, 16 inches wide assaying $30 per ton at 1200 feet, and 12 inches wide assaying $9 per ton at 1250 feet. Some gold was reported in all but a few assays from some 500 samples. At 900 feet the drill encountered a greenstone breccia from which water flowed at 80-pound pressure. A second hole on the Gold Road claim is reported to have cored 300 feet of greenstone.

Equipment included a Sullivan Machinery Company ''Beauty'' diamond drill driven by a Star automobile engine mounted on a steel frame, and a Gould New Pyramid pump driven by a Wisconsin air-cooled gasoline engine, Type A.K., size $2\frac{7}{8}$ by $2\frac{3}{4}$ inches. When it was decided to continue the hole beyond 1200 feet, a Knight and Stone diamond drill powered by a Model ''A'' Ford engine, and a Triplex pump driven by a Stratton gasoline engine, were substituted for the lighter equipment. Harold Johnson of Yreka was the drill operator on this job, and one assistant was employed. Studies made of the diamond-drill core suggest that there may be wide zones in the greenstones that could provide ore for a low-grade cyanide operation. (Brown 16, p. 837; Laizure 21, p. 534; Tucker 23, p. 11; Logan 25, p. 452; Averill 31, p. 45; 35, pp. 299-300, 323.)

Norcal Mining Company owned a group of claims about 5 miles south of Sawyers Bar in sec. 16, T. 39 N., R. 11 W., M. D. The group included the Ida May, Francis Ball, and Lucky Strike claims, which were sold to Jack Usher of Sawyers Bar, and are now part of the Security group. The Norcal Company has not operated since 1938. (Averill 35, pp. 261, 301, 324.)

Okoro Mines, Inc., Carl Weinhager Jr., St. Paul, Minnesota, president, operated a dragline dredge on the Scott River near Callahan on land owned by R. V. Hayden of Callahan. At first the operation employed a Marion dragline with a 2-cubic-yard bucket and a ''dry land'' washing plant built by the Bodinson Company on a steel chassis with Caterpillar treads $12\frac{1}{2}$ inches wide and 30 feet long. The trommel was 54 inches in diameter, 28 feet long, with 18 feet of three-fourths- to seven-sixteenths- and five-sixteenths-inch holes. Jigs were used in place of sluice boxes. Recovery was said to have been satisfactory, but the plant was discarded in June 1940 because the gravel was too deep for the equipment. Costs were up to 25 cents per yard and the gravel was only yielding 20 cents per yard. The washing plant was remodeled and a wooden hull 34 by 52 feet and 4 feet deep was built of 6-inch plank with asphalt joints, strengthened with wooden trusses and steel cables and tie rods at 4-foot intervals. The trommel was 54 inches in diameter and 28 feet long, with 18 feet of three-fourths- to five-sixteenths-inch holes. The stacker belt was 30 inches wide and 90 feet long, to take care of the expected depth of the gravel. A Dayton-Dowd impeller pump supplied 2500 gallons of water per minute. Steel sluices with Hungarian riffles were used in place of the jigs. This equipment was all electrically operated with power purchased from the California-Oregon Power Company. The plant had a capacity of 2500 yards per day to a maximum depth of 35 feet. The bedrock was hard. Test holes indicated that an average of 50 cents per yard could be mined, but in January 1942 only 103 ounces of gold and 10 ounces of silver were recovered from 60,000 yards. The operation was shut down. Fourteen men were employed under Lynn Rood, manager.

Oom Paul mine has one claim in sec. 12, T. 43 N., R. 10 W., M. D., and is owned by Lawrence A. Whipple of Greenview. It is leased with an option to purchase by Joe Meaders and Jerry Carlson. A quartz vein 4 to 20 inches wide strikes N. 35° W. and dips 50° N. The quartz is broken and stained brown, red, and black, and includes some ''sugar'' quartz and some with small vug holes. Both walls are andesite that is cracked and seamed. A quartz diorite dike 4 feet wide parallels the vein a short distance away along the hanging wall. An adit has been driven

on the vein for 50 feet. Meaders and Carlson are driving the adit ahead in the hope of developing sufficient ore to justify a small milling plant.

Oro Grande Mining Company (McKeen mine) owns 480 acres of patented land in sec. 36, T. 40 N., R. 9 W., M. D. It was under lease to Oils Incorporated in 1939. Six mineral-separation cells were added to the mill circuit, but the recovery was said to have been poor and the lease was abandoned in June 1940 after about 6 months of operation. Mill heads were said to have averaged $9.65 per ton. Hugh McKinney of Callahan, president of the company, claims that there is a recorded production of $250,000 from the property and that 25,000 tons of ore averaging $12 per ton is blocked out. This property is described in detail by Averill (31, p. 48). (Crawford 96, p. 419; Hamilton 22, p. 17; Brown 16, p. 838; Laizure 21, p. 534; Logan 25, pp. 453-454; Averill 35, pp. 302, 325.)

Quartz Hill mine includes about 75 acres of patented land on the Scott River at Scott Bar in sec. 16, T. 45 N., R. 10 W., M.D., owned by George C., Fannie E., and Emma L. Noonan of Scott Bar. Many rich pockets of gold have been recovered at this mine since it was first discovered in 1852. The gold occurs in quartz stringers and lenses in a gray to black micaceous schist. It is associated with fine-grained pyrite, and sometimes with galena. The mine was first worked by hydraulic methods and later by blasting the rock loose from the face and washing it through sluice boxes. Some of the quartz lenses have been mined by drifts and shafts, and the quartz milled in a 10-stamp mill. In 1941-42 George Noonan and George Milne had two men employed mining a quartz lens 4½ feet wide from an adit driven N. 83° E. for about 50 feet. They erected a timber headframe above a 75-foot incline shaft and mined a quartz vein from an old drift driven 180 feet east at the bottom of the shaft. A few pockets were mined in this work and the gold was recovered by grinding to 50-mesh in an Ellis mill and amalgamating on a copper plate 14 inches wide and 7 feet long.

The property was idle during the war, but in May 1947 Harry M. Thompson had a lease with an option to purchase and had 8 men employed prospecting the mine. Equipment included a Byers 83 power shovel and an Allis-Chalmers No. 10 bulldozer. The old 10-stamp mill was being put in shape to operate. Thompson says that the silver and gold telluride, petzite, is present in the ore. (Dunn 93, p. 447; Crawford 94, p. 290; 96, p. 421; Brown 16, p. 824; Averill 31, p. 49; 34, p. 307; 35, pp. 303, 325.)

Rainbow mine (Victory Gold Mines) includes four patented quartz claims, nineteen unpatented quartz claims, and four placer claims in secs. 16, 17, and 20, T. 40 N., R. 10 W., M.D. They were purchased in 1935 from the Victory Mines Company by the Rainbow Gold Mining Company, a Washington corporation controlled by William Winter and Son of Etna, California. Three men were employed prospecting quartz stringers in black schist in 1941. No production has been made for more than 10 years. (Logan 25, p. 459; Averill 35, pp. 311, 328.)

Roxbury Placer owns the Michigan Bar, Thomas, Junction Bar, and Johnson associated placer claims, which include 640 acres of patented land in secs. 6, 7, and 8, T. 45 N., R. 10 W., M.D. T. S. Rodgers of Spokane, Washington, leased this property and employed two men from September 1940 to June 1941 driving a 400-foot adit. He found that some of the old channel already had been drifted. Clarence Paulson of Spokane, and Edward F. Weber of Yreka prospected the property for possible dredg-

ing, but no operation resulted. The property was purchased from Henry L. Day of Wallace, Idaho, by James J. and Charles H. Brown of Scott Bar on August 20, 1946. (Logan 25, p. 484; Averill 35, pp. 257, 326.)

Sacchi-Spellenberg Mines. P. D. Sacchi, E. L. Spellenberg, and F. Kubli of Arcata operated a Judson Pacific dragline dredge with a 1½-cubic-yard bucket on the Salmon River near Forks of Salmon in 1939-40. The equipment was sold to Salmon River Dredging Company.

Salmon River Gold Dredging Company. George G. Titzell, 310 Kearney, Street, San Francisco, and J. P. Wood, Forks of Salmon, general partners, operated a dragline dredge on the Salmon River near Forks of Salmon and Sawyers Bar, and on the Klamath River near Happy Camp in 1941. Equipment was purchased from the Northern Dredging Company and included a Lima 1201 dragline with an 80-foot boom, a 2¾-cubic-yard Esco bucket, and a 250-horsepower Cummins diesel engine. The Bodinson washing plant was built of five steel pontoons making a hull 36 by 44 feet. The trommel was 54 inches in diameter and 28 feet long with an 18-foot length of screen. The stacker was 30 inches wide by 60 feet long. Water was supplied by a 12-inch United Iron Works centrifugal pump. There were nine 30-inch cross sluices, and three 30-inch downstream sluices on each side fitted with metal Hungarian riffles. Power was furnished by a Caterpillar D-13000 engine. F. A. Warren, Forks of Salmon, was dredgemaster.

Salmon River Mines Company (Trail Creek mine), E. C. Latcham, president and general manager, V. W. Peterson, secretary, Callahan, own seven claims in sec. 12, T. 39 N., R. 10 W., M.D. A quartz-stringer zone 5 feet wide is said to assay $12 in gold in the face of an adit 950 feet long. A 50-ton Marcy ball mill, 6 flotation cells, and other equipment for a small mill are said to have been purchased, but installation was delayed because of the war. (Averill 35, p. 307.)

Schroeder mine includes five patented and eight unpatented claims in sec. 17, T. 45 N., R. 8 W., M.D. Owner is Fidelity Metals Corporation, 2989 21st Avenue, San Francisco; agent is Major H. A. White, Yreka. In 1941 a partnership composed of Major White, George C. Phares, and two others had a lease and option, and the property was operated for a short time. The "1600" tunnel was reopened, and a winze was sunk to a depth of 96 feet on a vein 6 to 10 inches wide, striking N. 85° W. and dipping 74° S. Drifts were run 70 feet east and 40 feet west at the bottom of the winze. The vein was said to be 10 inches wide and to assay $40 per ton in the face of the east adit. The west drift was in waste because of a fault.

Equipment included a 3-drill capacity Ingersoll-Rand compressor, a Sullivan single-drum air hoist, and an air lift pump. The mill included a 6- by 8-inch Blake jaw crusher, a Straub ball mill grinding to 50-mesh, two 3- by 3½-foot amalgamating plates, and a Universal Overstrom table. Power was obtained by a Wisconsin 20-horsepower gasoline engine. The gold was said to be 85 percent free. The property has not been reopened since 1942. (Crawford 94, p. 291; 96, p. 424; Logan 25, p. 457; Averill 31, p. 53; 35, pp. 307, 326.)

Scandia No. 1 dredge, owned by Larsen Brothers and Harms Brothers, Route 4, Box 2220, Sacramento, was operating on Horse Creek in sec. 7, T. 46 N., R. 10 W., M.D., in December 1946. They purchased the mineral rights on a strip of land a quarter of a mile wide for a length of 4 miles along Horse Creek from its junction with the Klamath River,

and started dredging in section 15 in December 1938. It was stipulated that the soil would be stripped from meadowland, the tailings leveled, and the soil restored. This has been done. Equipment included a Marion 40-A dragline with a 60-foot boom using a 3-cubic-yard bucket. Power was furnished by a Cummins 250-horsepower diesel engine. The Bodinson washing plant had 8 steel pontoons making a hull 48 by 56 feet. The trommel was 60 inches in diameter, 42 feet long with 30 feet of five-sixteenths- to three-fourths-inch holes. Stacker belt was 36 inches wide and 60 feet long, and was operated by a 15-horsepower General Electric motor. Water was pumped by a United Iron Works 10-inch centrifugal pump, and a Rex speed prime 4-inch centrifugal pump. Power was furnished by a Caterpillar D-17000 engine. Electric lights were provided by a 1500-watt Koehler light plant. There were 12 cross sluice boxes 30 inches wide, and 2 downstream sluice boxes 30 inches wide on each side, fitted with Hungarian riffles.

The gravel was 15 to 18 feet deep above a soft black schist, and the operators were digging about 3500 yards in three shifts in December 1946. Cinnabar was found in the sands but was not saved. The top soil was about 2 feet deep in section 7, and a 200-yard width was stripped with a LeTourneau 12-cubic-yard carryall pulled by a D-8 Caterpillar tractor. The tailing from the dredge was leveled with a D-8 Caterpillar bulldozer and the soil replaced evenly for planting new crops. Eleven men were employed under R. I. Barritt, dredgemaster.

Scandia No. 2 (Moccasin) dredge, owned by Larsen Brothers and Harms Brothers, Route 4, Box 2220, Sacramento, was moved from the Klamath River near Horse Creek to claims in sec. 15, T. 16 N., R. 7 E., H., owned by Mrs. M. McCulloch of Medford, Oregon, and Joe Most of Seattle, Washington. Two extra pontoons 3 by 20 by 4 feet were added to each side of the hull to give it greater stability. Digging started on November 10, 1946. The gravel was 25 feet deep above a medium-hard black slate bedrock. Fifteen men were employed under Ray C. Henrici, dredgemaster.

Scott Bar Mines, Inc., includes 71.7 acres of patented land in secs. 16 and 21, T. 45 N., R. 10 W., M.D., owned by George A. Milne, Fort Jones. It adjoins the Quartz Hill mine on the east and is in the same formation of black micaceous schist with many stringers and lenses of white quartz. A quartz vein is developed by a 6- by 10-foot incline shaft 165 feet deep on a 40° slope in a N. 17° E. direction. Drifts were run on the vein at 100-, 155- and 165-foot depths. A fault at the bottom of the shaft strikes S. 15° E. and dips 40° south. A crosscut south is being driven to find the vein beneath the fault. The gold occurs in pockets in the white quartz and is associated with pyrite and galena. Several rich pockets have been mined from this property, which has a recorded production of over $41,000 from development work or an average of $10.93 per ton of rock excavated. Equipment includes a single-drum hoist driven by a Dodge engine, an Ingersoll-Rand 240-cubic-foot compressor, two Ingersoll-Rand jackhammer drills with shells and mountings, drill steel and accessory tools necessary to develop a small mine. A Sullivan core drill, Class H.S.15 has been purchased together with 300 feet of rods, three Model-7100A-C bevel bits, a Gardner-Denver 3- by 2- by 3-inch duplex pump, and an Ingersoll-Rand 315-cubic-foot portable air compressor. A diamond core-drilling development is planned. There is a small mill on the property which includes a jaw crusher, Ellis ball mill Type B1 with 40-mesh slotted screens, and a

2½- by 3-foot amalgamation plate. The jaw crusher is driven by a 3-horsepower Fuller Johnson gasoline engine, and the Ellis mill by a 3-horsepower John Deere gasoline engine. From three to six men are employed on development.

Security mine includes 7 unpatented claims in sec. 15, T. 39 N., R. 11 W., M.D., owned by John W. Usher of Sawyers Bar. An adit on the Soon Parted claim cut a 4-foot quartz vein striking northeast and dipping flatly southeast. The Soon Parted and Sandwich claims are leased to Melvin L. Usher and Leslie E. Dunbar, who plan to develop the vein and to install a 5-stamp mill on the property.

Siskiyou County mine includes 5 claims in sec. 31, T. 18 N., R. 7 E., H., owned by the James L. Wortham estate, Los Angeles, California. In November 1946 Leonard Crumpton of Happy Camp had a 5-year lease on this property and was repairing the ditch and pipe line from Mill Creek and preparing to operate. The bank is about 60 feet high with about 20 feet of gravel above a slate bedrock. There are many boulders that will have to be blasted or moved with a derrick. (Averill 35, p. 308.)

Smith and Myers mine. A small hydraulic mine was operated by Smith and Myers in 1941. It is located in Whites Gulch in sec. 26, T. 40 N., R. 11 W., M.D., about 3 miles east of Sawyers Bar. Water was brought from Whites Gulch through about a mile of ditch and flume and delivered to two No. 2 giants with 4-inch nozzles under 200-foot head. The gravel was washed through sluice boxes 3 feet wide, fitted with block riffles.

Starveout placer includes 3 claims on Arastra Creek in sec. 24, T. 48 N., R. 8 W., M.D., owned by R. A. Myers and R. A. Smith. Quartz stringers weathered from granodiorite are washed into a 12- by 12-inch sluice box 12 feet long fitted with Hungarian riffles. Water is obtained from a spring through about 100 feet of 12- by 12-inch flume, and is collected in a sump behind an earth-filled dam 9 feet high and 10 feet wide. Water for sluicing is pumped by a Jacuzzi Brothers 2½-inch centrifugal pump driven by a V belt from a Dodge automobile engine, and is discharged through 300 feet of fire hose having a seven-eighths inch nozzle. The loose weathered material that can be sluiced is 8 to 10 inches deep and yields some coarse gold.

Stenshaw (Klamath Gold Mining Corporation), Charles P. Franchot, president, Room 1636, 60 East 42nd Street, New York, N. Y., operated a hydraulic mine on the Klamath River about 9 miles above Somes Bar in secs. 28, 29, and 32, T. 13 N., R. 6 E., H., in 1937. Water was obtained under 250-foot head from Sandy Bar Creek through 1200 feet of flume and 2000 feet of 18- and 14-inch pipe, and from Stenshaw Creek under a 125-foot head by 500 feet of flume and 1200 feet of 18-, 16-, and 14-inch pipe. The gravel was about 25 feet deep above a soft slate bedrock and included many boulders that had to be blasted and lifted with a derrick. A No. 3 giant with 4½-inch nozzle, and a No. 4 giant with a 5-inch nozzle, were used in the pit. There were 500 feet of sluice boxes, 120 feet of which were fitted with angle iron and iron-shod wooden riffles. A Linco Engineering Company gold-saving machine was used in testing gravel and in cleaning up. It consisted of a small trommel and a centrifugal bowl, driven by a 3½-horsepower gasoline engine. The gravel was said to have averaged 25 cents per cubic yard. Eight men were employed in April 1937. There has been no recent operation. (Irelan 88, p. 604; Crawford 96, p. 428; Logan 25, p. 487; Averill 35, p. 327.)

Sunnyslope (Mullen) mine includes 5 claims in sec. 2, T. 40 N., R. 9 W., M.D., owned by J. A. Richter of Callahan. A quartz vein 2 to 7 feet

wide strikes S. 25° W., and dips steeply east. It has been crushed and broken and is stained yellow and brown from the oxidation of included pyrite. The walls are a fine-grained dark-gray rock, probably andesite. The Carry adit was driven N. 10° W. 70 feet to the vein, and then S. 25° W. for 50 feet on the vein, which was 5 feet wide at the face. About 8 tons of ore from this vein was ground to 40-mesh in a 2- by 5-foot ball mill driven by an International 5-horsepower gasoline engine. It is said to have yielded $70 in gold by amalgamation. No assays have been made to determine gold in the sulphides. The vein has been traced for over 500 feet on the surface by shallow shafts and trenches. Richter has been working alone on the property. (Averill 31, p. 47; 35, p. 324.)

Swede (Hickey) placer is owned by John Teuhert and leased to C. F. Thomain and Dan Sagaser of Sawyers Bar. It is in sec. 27, T. 40 N., R. 12 W., M.D., about 7 miles west of Sawyers Bar. Water is obtained from Alder Gulch through a ditch a mile long, and delivered through 120 feet of 11-inch pipe at a 108-foot head to a No. 2 giant with a 4-inch nozzle. There are 24 feet of sluice boxes 18 inches wide fitted with Hungarian riffles. The gravel bank is 30 feet high above a granite and serpentine bedrock. Boulders are plentiful. Operations were just starting when the property was visited March 21, 1947. (Crawford 94, p. 284.)

Trail Creek mine, see Salmon River Mines Company.

Vest Mining Company is a partnership composed of Frank Vest and Alfred Peeler of Seattle, Washington. They were operating a hydraulic mine in sec. 33, T. 40 N., R. 12 W., M.D., in March 1947. Water was obtained from Jones Creek through half a mile of ditch and 1500 feet of 36- to 15-inch steel pipeline. It was delivered under 120 feet of head to a giant fitted with a 2½-inch nozzle. A bank of angular gravel about 20 feet high was washed down to reach an old channel, a part of which was worked as a drift mine about 8 years ago by a miner named Neenach. The bedrock is decomposed granite. About 300 feet of 24- by 24-inch sluice boxes fitted with block riffles has been built. A derrick to handle boulders is operated by a double-drum hoist connected to a 36-inch Pelton water wheel. Four men were employed under Henry Seibert, foreman.

War Horse group of 13 claims in sec. 9, T. 45 N., R. 8 W., M.D., is owned by W. H. Price of Yreka. It is developed by an adit whose portal is about 300 feet west of and 60 feet higher than the No. 5 adit of the Eliza mine. The adit was driven S. 77° W. for 290 feet to a 12-inch quartz vein striking north and dipping 54° E. There are about 3 inches of black gouge on both walls of the vein which was said to assay $42.90 per ton. The quartz was said to assay $4 per ton in gold. The old Boyle mine is over the hill about half a mile to the west. The property is idle except for assessment work.

Webber Dredge (von der Hellen and Webber). Edward F. Webber, Box 217, Yreka, operated a dragline dredge on Humbug Creek about 2 miles south of the Klamath River in sec. 29, T. 46 N., R. 7 W., M.D. The dredge started at the mouth of Clear Creek in October 1939 as the von der Hellen and Webber dredge and reworked tailing from earlier placer-mining operations. In 1941 the dredge was purchased and operated by E. F. Webber. Equipment included a Lima dragline with a 60-foot boom and a 2-yard Esco bucket. It was powered by a Caterpillar D-17000 engine. The Judson Pacific washing plant was built of 5 steel pontoons making a hull 34 by 42 feet. The trommel was 60 inches in diameter and 30 feet long with 20 feet of three-eighths- to five-eighths-inch slots. Power

was furnished by a Caterpillar D-13000 engine. The stacker belt was 30 inches wide and 60 feet long between pulleys. There were 8 cross sluices 31 inches wide and 8 to 14 feet long discharging into 3 downstream sluices, 31 inches wide and 36 feet long, on each side. They were fitted with Hungarian riffles and mercury traps. In September 1941 the operators were digging about 100 tons per hour. The gravel was about 8 feet deep above a rough, hard bedrock, probably slate. There were many boulders. This equipment was moved to the Klamath River near McKinney Creek in sec. 9, T. 46 N., R. 9 W., M.D., on land owned by F. A. Jackson. It was shut down in September 1942 because of shortages of labor and supplies caused by the war. Some of the equipment was sent to war industries. Operations had not been resumed in March 1947.

West Branch Dredging Company is a partnership composed of Leslie G. Allen, G. B. Sutton, Donald Miller, Willard Landrum, and John Glassner of Fort Jones, California. The Beaver Dredging Company equipment was purchased in May 1942. The company owns 80 acres along Indian Creek in sec. 35, T. 45 N., R. 9 W., M.D. The gravel is from 6 to 12 feet deep above a slate and schist bedrock and is all old placer tailing. The equipment is the same as described under the Beaver Dredging Company except that the Model 1201 Lima Dragline has been replaced by a Model 6 Northwest dragline with a 50-foot boom, a 1½-cubic-yard bucket, and a Twin City gasoline engine. The equipment has been idle since June 1946.

White Bear mine (Mayland Mining Company) includes a group of 10 unpatented claims about 7 miles south of Sawyers Bar in sec. 18, 19, T. 39 N., R. 11 W., M.D. It is owned by the Mayland Mining Company, Harry J. Mills, managing director, and W. A. Harvey, mining engineer, Sawyers Bar. The property has been idle since the mill burned down about 10 years ago. The mine maps and assays indicate that quite a large tonnage of ore averaging $5 per ton in gold has been developed by drifts and raises from four adits. The last production was recorded in 1936. Manganese minerals outcropping on this property are described under "Mayland Mining Company," listed with manganese deposits. (Brown 16, p. 842; Averill 35, p. 311.)

White placer mine consists of two claims in sec. 12, T. 45 N., R. 8 W., M.D., owned by F. O. Jensen, Box 12, Yreka. Jensen and his son have been ground-sluicing these claims since 1938. Water for a No. 2 giant is obtained from Keeler Creek under about 100 feet of head. The gravel is sluiced through 120 feet of 24-by 16-inch boxes, the first 20 feet fitted with Hungarian riffles, the remaining 100 feet with pole riffles. The mine is worked 4 to 5 months each year while water is available.

Yreka Gold Dredging Company, 351 California Street, San Francisco, moved from Yreka Creek, just north of Yreka, and started operating on the Klamath River at Seiad in sec. 13, T. 46 N., R., 12 W., M.D., September 16, 1941. A detailed description of this bucket-line dredge is given by Averill (38, p. 123; 46, p. 300). A separate winch driven by a 40-horsepower General Electric motor was installed for the digging ladder, The ladder was lengthened 10 feet and the stacker belt 15 feet. At the Seiad location they were digging 20 feet of gravel and 2 feet of soft granite bedrock. Prospecting was done with a Keystone portable drill, and 6-inch holes were drilled at 100-foot intervals. Equipment includes an R.D.6 Caterpillar tractor, a D-6 Bulldozer, a 5-cubic-yard

LeTourneau carryall. A $1\frac{3}{4}$-cubic-yard Northwest dragline is used for digging canals and building levees. Twenty men are employed on three 8-hour shifts under Eric S. Peterson, dredgemaster. The Yreka Gold Dredging Company is consolidated with Arroyo Secco Gold Dredging Company of Ione, California, who own 277 acres in secs. 12, 13, and 14, T. 46 N., R. 12 W., M.D. (Averill 38, p. 123; 46, pp. 300-303.)

Yuba Consolidated Gold Fields (Siskiyou Unit), 351 California Street, San Francisco, California, owns a strip of land about 4 miles long and 1400 to 2700 feet wide along the Scott River in secs. 6 and 7, T. 40 N., R. 8 W.; sec. 1, T. 40 N., R. 9 W.; sec. 31, T. 41 N., R. 8 W.; and secs. 25 and 36, T. 41 N., R. 9 W., M.D.

The Yuba No. 116 bucket-line dredge was built on sec. 7, T. 40 N., R. 8 W., in 1936. It has a steel hull 122 feet 8 inches by 56 feet, and 10 feet deep. The digging ladder is 93 feet long with 70 buckets, capacity 9 cubic feet each, and they are pulled at the rate of 22 to 24 buckets per minute by a 350-horsepower Westinghouse motor. The trommel is 8 feet in diameter and 48 feet long, with 34 feet of three-eighths- to five-eighths-inch holes, and is rotated at 7 revolutions per minute by a 75-horsepower Westinghouse motor. The stacker belt is 36 inches wide and 136 feet long between pulleys and is operated by a 50-horsepower motor. A Byron-Jackson high-pressure 12-inch centrifugal pump is operated by a 100-horsepower motor, and a 12-inch centrifugal low-pressure pump is operated by a 50-horsepower motor. On each side of the trommel the cross sluice boxes are double banked with four 32-inch sluices above eleven 32-inch cross sluices discharging into nine 32-inch downstream sluices fitted with steel-shod wooden riffles. The swing winch is operated by a 50-horsepower electric motor. Water pumped by a 6-inch Byron-Jackson centrifugal pump driven by a 40-horsepower motor was used to wash the gravel in the hopper; a 4-inch Byron-Jackson centrifugal pump was used in the clean-up and for fire protection.

In June 1941, a Yuba bucket idler was installed, which made it possible to dig an additional 5 feet in depth to a maximum of 40 feet. The gravel in sec. 1, T. 40 N., R. 9 W. was only 12 feet deep above a hard serpentine bedrock, but test holes have shown 36 to 52 feet of gravel ahead. The boat was operated 24 hours per day with 11 men on the dredge crew, one caterpiller bulldozer operator, two shoremen, one retortman, one electrician, one carpenter, one machinist, two shopmen, one truck-driver, and one field clerk, a total of 22 men, under W. B. Lewis, dredge-master. The dredge was shut down April 15, 1946, and it was planned to add three rollers and an additional 21 feet in length to the digging ladder. Four additional pontoons had been added to the hull and it was planned to add two more. There will be 75 buckets on the line when the remodeling is completed. About 3 years operation remains at this location. (Averill 38, p. 126.)

Zarina mine includes nine unpatented claims in sec. 27, T. 41 N., R. 10 W., M.D., owned by John J. Stanning of Etna, California. A quartz vein 2 feet wide with schist walls was developed by two adits and drifts and stopes. The property has been idle for many years and the adits are caved at the portals. The mine buildings, with the exception of one log cabin, are all wrecked. There is no mine equipment at the property. (Brown 16, pp. 822, 842; Averill 35, p. 329.)

Graphite

Black Jack (Crystal, Elk Lake) group of three claims and a mill site in sec. 12. T. 47 N., R. 12 W., M. D., were located by Elwood R. and William B. Stewart, Mrs. Cora Maddron, and W. H. Gassoway, in 1941. They are reached by about a mile of rough trail from the Forest Service road at the Cook and Green Pass. Graphite occurs finely disseminated in sandstone and in cracks and narrow seams near a contact with andesite. Very little prospecting has been done on these claims and no attempt has been made to determine the grade of ore that might be produced.

Limestone

Many large deposits of limestone and marble outcrop in Siskiyou County, and those located favorably in regard to roads and railroad transportation have been mined from time to time. The deposits outcropping about 3 miles west of the railroad at Gazelle are mined, processed, and sold as agricultural limestone, "carbide rock", road metal, and for use in sugar refining. They are the closest source of agricultural limestone for areas in Oregon with soils deficient in that necessary mineral.

Electro Lime and Chemical Corporation, C. J. Montag, president, Dr. L. Underdahl, vice-president, P. M. Sherlund, treasurer, and G. R. Bethel, secretary, have offices at 536 Southeast Sixth Avenue, Portland, Oregon. The limestone is mined from a deposit in secs. 4, 5, and 8, T. 42 N., R. 6 W., M.D., owned by Sisto Mazzuchi of Gazelle. It is drilled by two men using jackhammers on wagon-drill mountings. Holes are spaced at 5-foot intervals, drilled 20 feet vertically, loaded with 40-percent dynamite, and blasted. The broken limestone is loaded onto dump trucks with a 1-cubic-yard Lorain shovel and hauled 3 miles to the crushing and screening plant at Gazelle. There it is dumped into a 20-ton-capacity wooden bin from a ramp and fed into a 24- by 36-inch jaw crusher by a 30-inch Lipman feeder. The jaw crusher discharges minus 3-inch material onto a 24-inch conveyor belt 70 feet long which delivers it to a 3- by 10-foot Pioneer double-deck vibrating screen driven by a $7\frac{1}{2}$-horsepower motor. Material over $1\frac{1}{2}$-inches and under $\frac{1}{2}$-inch is delivered to a 3XC-type Grundler hammer mill driven by a 220-horsepower diesel engine. The $1\frac{1}{2}$- to $\frac{1}{2}$-inch size goes to a bin for sale as "carbide rock". The hammer-mill product is raised 28 feet with a bucket elevator to a 4- by 12-foot, 3-deck Seco vibrating screen fitted with 8-mesh screens. The oversize is stockpiled. The undersize is classed as agricultural limestone and is weighed by an "OK" weighing machine into paper bags holding 100 pounds each, or is loaded in bulk on cars or trucks for shipment. Material sold for agricultural limestone is specified as 100 percent minus 8-mesh, 50 percent minus 50-mesh, and 35 percent minus 100-mesh. It has a minimum of 95 percent $CaCO_3$ and a maximum of 1 percent $MgCO_3$. Material from half an inch to $1\frac{1}{2}$ inches in size is classed as "carbide rock" and is used in the manufacture of calcium carbide.

Four men were employed at the quarry and seven men at the mill under George E. Bethel, superintendent, in May 1947. Production was at the rate of 150 tons per 8-hour day.

Mt. Shasta limestone deposit is located about 4 miles west of Gazelle in sec. 12, T. 42 N., R. 7 W., M.D. It is on patented land owned by E. M. Greenwood. It was leased and operated by M. C. Lininger and Sons, Medford, Oregon, in 1945. The limestone was broken in benches by

drilling vertical holes about 20 feet deep spaced 5 feet apart, and blasting with 40-percent dynamite. The broken limestone was loaded into dump trucks with a three-fourths-cubic-yard Northwest power shovel. It was crushed in a 24- by 36-inch Telesmith jaw crusher and screened with a Symons vibrating screen having 2-inch and 6-inch screens. About 1200 tons of hard blue limestone between 2 and 6 inches in size was shipped each week on a 25,000-ton contract. It was used by a sugar refinery. Material under 2 inches in size was stockpiled. (Averill 35, pp. 331, 332.)

Lead

Balfrey (Siskiyou Lead) mine. Eight hundred acres of patented land in secs. 28 and 29, T. 41 N., R. 7 W., M.D., are owned by M. H. Balfrey of Etna, California. Small amounts of galena and fine-grained sphalerite, and rarely chalcopyrite, occur in shear zones in andesite. The sulphide minerals are accompanied in some places by calcite and barite. The old shafts and adits on this property are caved and inaccessible. Although showings of galena have been prospected by shallow pits in many places over these claims, the mineralization was not sufficient to encourage the operators to do much development work. All machinery and equipment have been removed from this property and it has been idle since 1929. (Averill 35, pp. 274, 314.)

Manganese

Manganese deposits occur in the western part of Siskiyou County, and prospects have been examined in the Fort Jones, Oro Fino, Happy Camp, Seiad Valley, and Sawyers Bar districts. Although some of the outcrops are quite extensive, the grade of the ore, and especially the high silica content, would not meet the minimum Metals Reserve Company specifications, and little ore was mined. Thirty-one manganese deposits in Siskiyou County were listed by Trask (43, pp. 183-185, map), a few of which are described here.

Colgrove Manganese (Fort Jones). W. J. Colgrove and Max Erwin of Fort Jones had three men employed mining and sorting manganese ore from an outcrop on patented land in sec. 2, T. 43 N., R. 9 W., M.D., leased from Frank Jordan of Fort Jones. The outcrop was about 12 feet wide between andesite walls. Pyrolusite was so intimately mixed with white quartz and brown limonite that sorting to meet the Metal Reserve Company specifications of May 1942 could not be done.

Fort Jones Manganese, see Colgrove manganese.

Gray Ledge mine is located on Music Creek about 2 miles east of Finley Camp in sec. 21, T. 40 N., R. 10 W., M.D. It was operated by E. A. von Gerlitz of Sawyers Bar, and W. B. Stewart of Fort Jones in 1943-44. They shipped 231 tons of manganese ore to the Metals Reserve Company stockpile at Yreka, which averaged 40 percent manganese and 15 percent silica. The chief minerals were rhodochrosite and hausmannite.

Jim Allen mine. One claim in sec. 8, T. 44 N., R. 8 W., M.D., is owned by John F. Lewis and Robert Reynolds of Fort Jones. In June 1942 it was under lease to Max Erwin and Ronald Knudsen of Yreka. A 23-foot width of black manganese streaked with spongy quartz and brown limonite was exposed in three bulldozer cuts. It was too high in silica to meet the Metals Reserve Company specifications and no production was recorded.

8—76940

Mayland Mining Company (White Bear mine) holds 10 unpatented claims in secs. 18 and 19, T. 39 N., R. 11 W., M.D., about 7 miles south of Sawyers Bar. Bands of black manganese and white quartz with some pink rhodonite and rhodochrosite outcrop for a width of about 150 feet below the Sawyers Bar-Cecilville road. The manganese ore was too low in grade and too high in silica to meet the Metals Reserve Company specifications. (Trask 43, p. 184.)

Mineral Water

Shasta Water Company, J. J. Nagy, president, Sixth and Brannan Streets, San Francisco, California, owns Shasta Springs, located about 2 miles north of Dunsmuir in sec. 7, T. 39 N., R. 3 W., M. D. The natural carbonated water issuing from the spring is pumped into three 3500-gallon-capacity glass-lined steel tanks. It is allowed to settle for 3 days and is then decanted and pumped into railroad tank cars lined with block tin, and shipped to distributing plants in San Francisco, Seattle, Los Angeles, Portland, and Sacramento. The water is filtered through rock before bottling and is recharged with carbon dioxide. Herman Utah is superintendent at the springs.

The cabins and hotel accommodations available at Shasta Springs Resort are operated by the Thompson Hotel Company, Harry Price, manager. The springs of Siskiyou County are described in the following reports and bulletins: Crawford 96, p. 520; Watts 93, pp. 449-452; and G. A. Waring 15.

Stewart Mineral Springs in sec. 11, T. 41 N., R. 6 W., M. D., is owned and operated by Mrs. Kathryn Lloyd, Box 507, Edgewood, California. A cold-water spring said to contain medicinal minerals has been developed for drinking and bathing. There are 14 guest cabins with tub baths and a community kitchen and dining room. The water is heated for the baths.

Analysis of Stewart Springs water	P.P.M.
Total solids	3470.00
Volatile and organic matter	750.00
Alkalinity as $CaCO_3$	647.50
Silica	25.20
Iron and aluminum oxides	2.30
CaO	3.10
MgP_2O_7	Trace
SO_3	207.67
Chlorine	1014.28

Table Rock Spring, in sec. 20, T. 45 N., R. 4 W., M.D., is owned by the Sidney F. Terwilliger estate. No commercial production has been made from this spring since 1945. The water was formerly bottled as a carbonated natural mineral water by the Yreka Coca Cola Bottling Works, Fred J. Meamber, proprietor, 412 South Main Street, Yreka.

Analysis of Table Rock Spring water	P.P.M.
Silica	452
Iron and aluminum oxides	2.30
Aluminum oxide	21
Magnesium bicarbonate	128.8
Calcium bicarbonate	556.6
Sodium bicarbonate	3010.7
Sodium sulphate	4.3
Sodium chloride	797.1
Total solids	4545.1

Molybdenite

Molybdenite was present in the ore mined at the Yellow Butte mine mentioned above under the heading *Copper*.

Ornamental and Gem Stones

Californite ("California jade") is a very compact, massive green vesuvianite, which takes a high polish and resembles jade. It occurs as streaks and nodules in serpentine. The deposit on the *Chan jade claim* on the South Fork of Indian Creek about 10½ miles north of Happy Camp, is owned by J. L. Kraft, 455 East Grand Avenue, Chicago, Illinois. No commercial production is made from the deposit.

Platinum

The platinum-group metals occur in a very low ratio to the amount of gold in the placer mines, and only a small amount has been recovered in Siskiyou County. C. A. Logan (19) reported that the platinum-group metals are found in appreciable amounts only where serpentine and peridotite outcrop in the drainage basin of the placers. At the Michigan Salmon hydraulic mine, a few miles below Forks of Salmon, some almost pure osmiridium was recovered.

Yuba Consolidated Goldfields have recovered some platinum in their dredging operations on the Scott River below Callahan.

Pumice

Pumice is a very porous volcanic glass formed when great quantities of steam and other gases expand and escape from cooling molten lava. It occurs as a crust on lava flows and in beds where it was blown from erupting volcanoes. It often has a silky luster, and a cellular structure which makes it light enough to float on water. It is usually white or gray in color and has the composition of rhyolite or andesite. Scoria is a type of volcanic material formed from stiff basalt lavas and has larger holes more widely spaced than pumice.

The pumice deposits of Siskiyou County are located along the northern and eastern edges of the glass flow from Glass Mountain, and occur in horizontal beds some 14 feet thick at the edges of the flow, grading to about 2½ feet thick a mile away. The pumice is fragmental, white to gray in color, and has an average maximum size of about 1 inch. Few pieces are over 2 inches in size.

Mining consists of stripping the surface of the beds free of shrubbery and forest litter with a bulldozer for an area about 100 feet square. Dump trucks of 5 to 7 cubic yards capacity are then loaded by a variety of apparatus including portable bucket elevators, dragline scrapers, power shovels, and from bins filled by bulldozers pushing the pumice over a ramp. The pumice when mined contains from 20 to 25 percent moisture and weighs about 1300 pounds per cubic yard. The railroad classifies it as a pumice scoria and has set a weight-equivalent of 1000 pounds to a cubic yard. It is hauled to sidings on the Great Northern Railroad at Tionesta and Ainshea Butte, where the bulk of it is loaded onto open gondola cars for shipment to west-coast cities. A small amount is shipped by truck to Klamath Falls processing plants, and some is made into building blocks at plants near Tionesta. Raw pumice sold for $2 per yard, and material ground to minus one-fourth-inch sold for $3 per yard on the cars at Tionesta in September 1946. Pumice bricks 3½ by 3½ by 6 inches in size are sawed from blocks of

pumice broken from the crust of lava flows near the summit of Glass Mountain.

Fouch Claims. Roy Nial Fouch of Tionesta claimed about 900 acres of land on the north slope of Glass Mountain in secs. 22, 27, and 34, T. 44 N., R. 4 E., M. D. On the Christy claim in the SE$\frac{1}{4}$ sec. 27, the pumice is about 14 feet deep above a sandy basalt. It is mined with a 1-cubic-yard slusher powered by a double-drum donkey hoist, chain-driven by a Chevrolet 6-cylinder automobile engine. The pumice is loaded into a 30-cubic-yard-capacity bin built of timbers, from which it can be loaded into trucks for hauling to the railroad, a distance of about 10 miles. In September 1946 Fouch was working alone at this property loading about a carload of pumice aggregate per day for C. V. Enloe, Jr., who was shipping from Ainshea Butte.

Glass Mountain Industries, owned by Charles P. von Doren, Box 648, Klamath Falls, Oregon, is a group of claims located on Glass Mountain in secs. 34, 35, T. 44 N., R. 4 E., M. D. A truck road has been built up the eastern slope of the mountain over the glass flow and obsidian boulders to an area where many of the obsidian boulders have a crust of pumice as much as 12 inches thick. Pumice boulders having the desired texture are sorted and loaded into trucks and hauled to Klamath Falls where they are sawed into scouring bricks.

Glass Mountain Volcolite Company. H. W. Free of Tionesta claims some 1720 acres in secs. 1 and 2, T. 43 N., R. 4 E., and secs. 25, 26, 34, 35, and 36, T. 44 N., R. 4 E., M. D. The bulk of his production has been used as aggregate in the manufacture of building blocks in his plant at Tionesta. Some scouring bricks have been produced from blocks mined on these claims.

John Madsen of Klamath Falls, Oregon, claims 280 acres of land in secs. 25, 26, and 35, T. 44 N., R. 4 E., M. D. A road cut near his cabin in the SW$\frac{1}{4}$ sec. 26 opened a bed of pumice 10 feet deep, but there has been no production. Madsen has been sawing scouring bricks from pumice blocks mined in Modoc County.

Mount Hoffman pumice claims include 960 acres in sec. 28 and the E$\frac{1}{2}$ sec. 29, T. 44 N., R. 4 E., M.D. Some of the first pumice aggregate produced in Siskiyou County was mined from these claims in 1935 by E. L. Jamison, J. O. Miller, and Dan A. Williams. The property has been idle since 1942, but a ''desire to hold'' notice has been filed by Dan A. Williams, 217 Monterey Street, Salinas, California. (Averill 35, p. 335.)

Shasta Group. Twelve claims on the south slope of Cinder Cone Mountain in sec. 22, T. 42 N., R. 4 W., M.D., are owned by Clem and Nettie Baker of Yreka. Black volcanic cinders are mined from a pit about 300 feet long by backing a truck up to the slope and scooping the cinders into a trough slide to the truck. Very little of the material is over an inch in size. The depth of cinder deposit has not been determined, but the length is about 2000 feet. The cinders weigh 40 pounds per cubic foot and are used as a substitute for, or mixed with pumice as an aggregate in the manufacture of concrete blocks in building construction and as an insulation material.

Volcanic Products Corporation, Paul Dalton, manager, Williams Building, Klamath Falls, Oregon, owned and leased unpatented mining claims including 3411 acres near Glass Mountain in T. 44 N., R. 4 E., M.D., in 1937. Some of the claims were leased from the Christie estate,

and others from R. N. Fouch of Klamath Falls, Oregon. Pumice of a maximum size of 1½ inches occurs in pits to a depth of 40 feet. It was mined by a five-eighths-cubic-yard Byers gasoline shovel and hauled to a crushing and screening plant at Leaf on the Southern Pacific Railroad. The plant included a set of rolls and a vibrating screen operated by an 80-horsepower Hercules gasoline engine. The product was sold for concrete aggregate.

Scoria boulders are found overlying the glass on the mountain, and they were sawed into scouring blocks on a 36-inch diameter circular saw having teeth faced with a hard alloy. A 12-inch carborundum-disc saw was used for trimming the bricks and a gang of five 16-inch-diameter mild-steel saws were used for sawing the bricks with powdered carborundum. A Dodge automobile engine furnished the power. Twenty-seven men were employed at the mine and six men at Leaf in July 1936. Production in 1936 amounted to 4000 cubic yards of pumice worth $14,000. f.o.b. railroad, and 15,000 pumice bricks 3 by 4 by 6 inches which sold for 10 cents each. No production has been reported by this company since 1938 and the properties they held are now operated by other interests.

Quicksilver

Great Northern quicksilver (Herzog-Morgan, Minnehaha, Empire Canyon Mining Company, Mercury) mine includes 15 quartz and 2 placer claims located in sec. 13, 14, and 24, T. 47 N., R. 8 W., M.D. J. C. Humphrey, legal owner, leased the property in March 1940 to C. N. White and C. W. Yates of Yreka. At an elevation 160 feet lower than the LeRoy level, a crosscut adit was driven N. 8° W. 455 feet to a vein 20 inches wide striking N. 20° E., and dipping 58° W. Native quicksilver and cinnabar occur in cracks and vugs in the brecciated vein filling. The vein was developed by drifting south for 150 feet and north 125 feet. Stopes about 30 feet long were worked above both drifts. The north drift was stoped 125 feet to the surface. The stope in the south drift was about 30 feet high and pinched out. A winze was sunk 60 feet deep below the LeRoy level at a point about 300 feet south of the adit. Ore from these developments, together with some of the gob from the old stopes, was sent to the new mill.

Ore was dumped from the mine cars through a 6-inch rail grizzly into two steel cylindrical ore bins, 8 feet in diameter and 24 feet high, equipped with steel gates. It was dropped from the bins through a 2- by 4-foot steel-slide grizzly with bars spaced at three-quarters of an inch. The oversize was crushed to 1½ inches in an 8- by 10-inch jaw crusher and joined the undersize on a belt-conveyor 14 inches wide and 77 feet long, which delivered it to a 12- by 12-foot steel cylindrical bin. This bin had a cone-shaped bottom fitted with an 8-inch pipe 4 feet long, which discharged the ore on the top hearth of a five-hearth, Nichols Herreshoff furnace. The furnace had a 10-foot-diameter steel shell lined with fire brick. Two rake arms revolved at 1 revolution per minute. Butane gas was mixed with air from a Victor-Acme type A.F. size 17 blower in two Hauck burners to provide heat at 1400 to 1450 degrees Fahrenheit. The furnace vapors were pulled through a Sirroco dust collecter by a 24-inch fan which created a vacuum of 5 to 6 inches water-gage, and were delivered through a surge tank to two banks of condenser pipes. There were eleven cast-iron pipes, 8 inches in diameter by 18 feet in length, in each bank. They discharged under water into cast-iron pans. The quicksilver and sludge from the pan was mixed with lime in a sheet-iron box

and the clean quicksilver weighed into flasks. The installation had a capacity of 24 tons per 24 hours.

Mine equipment included a Gardner-Denver 310-cubic-foot portable compressor, two jackhammers, and a stoper drill, together with accessory fittings and small tools.

The Empire Canyon Mining Company, Carl Yates, manager, succeeded White and Yates as operators in November 1941. In October 1942, B. W. Burtch of Seattle took over the operation and had some 16 men employed under Wm. S. Barquist, superintendent. After a short operation the plant was purchased by Edward F. Webber of Yreka who dismantled and sold the plant and equipment. (Averill 35, p. 336; Logan 25, pp. 495-496.)

Horse Creek Mercury. Small amounts of cinnabar occur in seams and cracks in a hornblende schist on the west bank of Horse Creek in secs. 15 and 16, T. 46 N., R. 10 W., M.D. It has been prospected by numerous short adits and shallow cuts, but no production has resulted. Cinnabar was recovered with the black sand in the dredging operations on Horse Creek but it was not retorted.

Sandstone

Sandstone beds outcropping in Shasta Valley were quarried and used in general construction prior to 1918. Many of the culverts on the Southern Pacific Railroad were built of sandstone. The following quarries were described in earlier reports of the Division of Mines.

Antone or *Weeks quarry* is 2 miles northeast of Yreka. The sandstone was quarried in layers from 6 inches to 8 feet thick and was used for building in Yreka. (Averill 35, p. 337.)

Fiock Brothers quarry is in sec. 13, T. 45 N., R. 7 W., M.D., near Yreka. The stone is coarse grained, even textured, and tawny in color. (Averill 35, p. 337.)

Southern Pacific Company has quarried considerable sandstone in sec. 29, T. 47 N., R. 6 W., M.D., near Hornbrook. This stone has been used for railroad culverts and for some buildings in Hornbrook. (Averill 35, p. 337.)

Silver

The silver produced in Siskiyou County has come as a by-product of gold and copper mining and amounts to about $260,000 in value.

Stone, Miscellaneous

Clements and Company of Hayward, California operated a gravel plant near Gazelle in sec. 10, T. 42 N., R. 6 W., M.D., on land owned by J. Robert Scott. The gravel was dug with a Northwest dragline equipped with a 40-foot boom and a three-fourths-cubic-yard bucket. It was crushed and screened to minus one-eighth-inch, mixed with oil in a Madsen No. 95 hot plant and used for building a stretch of Highway 99 north of Gazelle in June 1946.

Mount Shasta (Kottinger) gravel pit is located about 2 miles northwest of Mount Shasta in sec. 5, T. 40 N., R. 4 W., M.D., on ground owned by the McCloud River Railroad. The lease and equipment were purchased by J. S. Jensen and M. M. Thompson from A. E. Kottinger in August 1945. An andesitic gravel is dug to water level from pits about 25 feet deep. Equipment includes a P & H dragline with a 40-foot boom and a three-fourths-cubic-yard bucket; a Byres three-eighth-cubic-yard shovel; and a portable bucket line loader having 24 buckets 14 inches wide and 3

inches deep, chain driven from a Fordson tractor engine. Trucks are dumped into a hopper through a rail grizzly with 6-inch openings, and the gravel is fed into a jaw crusher set at 2 inches. The minus 2-inch material is lifted 40 feet with a bucket elevator to discharge over a triple-decked vibrating screen fitted with 1-inch, half-inch and quarter-inch screens. Sixty percent of the material is over a quarter of an inch in size and is classed as rock. Material that passes through a one-fourth-inch screen is classed as sand. Gravel is made up of half sand and half rock. Material over 1 inch in size is crushed in a Telesmith gyratory crusher and discharged over the vibrating screen from a bucket elevator. Most of the material is sold for concrete aggregate. Three men were employed at this pit in March 1947.

A. Young, South Highway 99, Yreka, loads sand and gravel from old dredge tailing piles on Greenhorn Creek, Yreka Creek, and from an old creek bottom about half a mile east of Gazelle, which he has leased from F. Foulke. The gravel is loaded with power shovels into dump trucks and hauled to his Yreka plant where it is crushed and screened to the desired sizes for use as concrete aggregate or for road construction.

BIBLIOGRAPHY

Allen, John Eliot

41 Geological investigation of the chromite deposits of California: California Div. Mines Rept. 37, pp. 101-167, 31 figs., 1941. (Siskiyou County, pp. 123-130.)

Aubury, Lewis E.

05 The copper resources of California: California Min. Bur. Bull. 23, 282 pp., illus., map, 1905. (Siskiyou County, pp. 102-111.)

08 The copper resources of California: California Min. Bur. Bull. 50, 366 pp., illus., maps, 1908. (Siskiyou County, pp. 120-133.)

Averill, Charles Volney

31 Redding field district—preliminary report on economic geology of the Shasta quadrangle: California Div. Mines Rept. 27, pp. 2-65, illus., 1931.

34 Redding field district—current mining development in northern California: California Div. Mines Rept. 30, pp. 303-309, 1934. (Siskiyou County, pp. 306-308.)

35 Redding field district—mines and mineral resources of Siskiyou County: California Div. Mines Rept. 31, pp. 255-338, illus., map, 1935.

38 Gold dredging in Shasta, Siskiyou, and Trinity Counties: California Div. Mines Rept. 34, pp. 96-126, illus., 1938.

46 Placer mining for gold in California: California Div. Mines Bull. 135, 377 pp., 4 pls., 106 figs., 1946. (Siskiyou County, pp. 293-303.)

Bradley, Walter W.

18 (et al.) Manganese and chromium in California: California Min. Bur. Bull. 76, 248 pp., illus., 1918.

Brown, G. Chester

16 Siskiyou County: California Min. Bur. Rept. 14, pp. 810-872, illus., 1916.

Crawford, J. J.

94 Twelfth report of the State Mineralogist, (second biennial), two years ending September 15, 1894: California Min. Bur. Rept. 12, 541 pp., illus., 1894.

96 Thirteenth report (third biennial) of the State Mineralogist for the two years ending September 15, 1896: California Min. Bur. Rept. 13, 726 pp., illus., 1896.

Diller, Joseph Silas

03 Klamath Mountain section, Cal.: Am. Jour. Sci., 4th ser., vol. 15, pp. 342-362, 1903.

14 Auriferous gravels in the Weaverville quadrangle, Cal.: U. S. Geol. Survey Bull. 540, pp. 11-21, map, 1914.

Dunn, R. L.

93 Siskiyou County: California Min. Bur. Rept. 11, pp. 420-449, 1893.

Haley, Charles Scott

23 Gold placers of California: California Min. Bur. Bull. 92, 167 pp., illus., maps, 1923.

Hamilton, Fletcher

22 A review of mining in California during 1921 with notes on the outlook for 1922: California Min. Bur. Preliminary Rept. 8, 68 pp., 1922.

Hershey, Oscar H.

01 Metamorphic formations of northwestern California: Am. Geologist, vol. 27, pp. 225-245, 1901.

12 The Belt and Pelona series: Am. Jour. Sci., 4th ser., vol. 34, pp. 263-273, 1912.

Hobson, J. B.

90 Siskiyou County: California Min. Bur. Rept. 10, pp. 655-658, 1890.

Irelan, William Jr.

88 Eighth annual report of the State Mineralogist for the year ending October 1, 1888: California Min. Bur. Rept. 8, 948 pp., illus., 1888. (Siskiyou County, pp. 581-631.)

Jenkins, Olaf P.

35 New technique applicable to the study of placers: California Div. Mines Rept. 31, pp. 143-210, pl. 3, 34 figs., 1935.

38 Geologic map of California, scale 1:500,000, California Div. Mines, 1938.

Laizure, C. McK

21 Siskiyou County: California Min. Bur. Rept. 17, pp. 529-536, 1921.

Logan, Clarence A.

19 Platinum and allied metals in California: California Min. Bur. Bull. 85, 120 pp., illus., 1919.

25 Sacramento field division—Siskiyou County: California Min. Bur. Rept. 21, pp. 413-498, illus., 1925.

Maxson, John H.

33 Economic geology of portions of Del Norte and Siskiyou Counties, northwesternmost California: California Div. Mines Rept. 29, pp. 123-160, 26 figs., map, 1933.

O'Brien, J. C.

43 Current notes on activity in the strategic minerals, Redding field district: California Div. Mines Rept. 39, pp. 77-84, 1943. (Siskiyou County, pp. 82-83.)

43a Current notes on the activity in the strategic minerals, Redding field district: California Div. Mines Rept. 39, pp. 323-330, 1943. (Siskiyou County, pp. 327-329.)

Trask, Parker D.

43 (**Wilson, I. F.**, and **Simons, F. S.**) Manganese deposits of California—a summary report: California Div. Mines Bull. 125, pp. 51-215, 2 figs., map, 1943. (Siskiyou County, pp. 88, 183-185.)

Tucker, W. Burling

22 Redding field division: California Min. Bur. Rept. 18, pp. 295-298, 1922. (Siskiyou County, pp. 297-298.)

22a Redding field division: California Min. Bur. Rept. 18, pp. 595-601, illus., 1922. (Siskiyou County, p. 600.)

22b Redding field division: California Min. Bur. Rept. 18, pp. 729, 736, illus., 1922. (Siskiyou County, p. 733.)

23 Redding field division—review of mining during 1922: California Min. Bur. Rept. 19, pp. 7-13, 1923.

23a Redding field division: California Min. Bur. Rept. 19, pp. 135-140, 1923. (Siskiyou County, pp. 138-139.)

23b Redding field division: California Min. Bur. Rept. 19, pp. 55-59, 1923. (Siskiyou County, p. 58.)

United States Geological Survey

43 Department of the Interior information service: California Div. Mines Rept. 39, pp. 90-102, 1943. (Chromite deposits of McGuffy Creek area, Siskiyou County, California, pp. 92-94; The Fairview and Ladd chromite deposits, Siskiyou County, California, pp. 94-96.)

Waring, G. A.

15 Springs of California: U. S. Geol. Survey Water-Supply Paper 338, 410 pp., 13 pls., 1915.

Watts, W. L.

93 Mineral springs in Siskiyou County: California Min. Bur. Rept. 11, pp. 449-452, 1893.

SILVER

By W. B. Winston*

OUTLINE OF REPORT

PROPERTIES AND MINERALS

Silver (Anglo-Saxon, ''Soelfor''; L. argentum), Ag, is found native and in ores in combination with non-metallic elements. The metal is pure white and has a brilliant luster. It is a little harder than gold and is excelled only by that metal in malleability and ductility; it excels all other metals as a conductor of heat and electricity; it undergoes no change in water or pure air, but absorbs 22 times its volume of oxygen when melted, which is again expelled on cooling; it tarnishes in the vapors of sulphur compounds forming the black sulphides (Ag_2S). The most important compounds of silver are the sulphide, the nitrate ($AgNO_3$) or lunar caustic, the oxide (Ag_2O), and the halides ($AgCl$, $AgBr$). One property of the latter, darkening on exposure to light, is the basis of photography.

The economic minerals of silver are metallic silver, argentite, argentiferous galena, cerargyrite, proustite, pyrargyrite, stephanite, tetrahedrite, and polybasite. The most important ores are the silver-bearing lead ores in which the heavy mineral is principally argentiferous galena usually associated with pyrite, sphalerite, and rich silver-bearing minerals. The usual gangue minerals are quartz, calcite, barite, and chert.

Native silver (metallic silver) crystallizes in the cubic hexoctahedral class. The crystals are usually small and distorted and in parallel groups. The cube and octahedron are most common. Silver commonly occurs in acicular forms, reticulated or arborescent in shape; in fine threads or wires, sometimes matted and resembling tufts or wads of hair; also in plates or flattened scales, or large masses. Color and streak are silver-white, or gray to black when tarnished. The luster is brilliant metallic. Silver has no cleavage, and is ductile and malleable. The hardness is 2.5 to 3; and the specific gravity, 10 to 12, pure 10.5. Silver often contains varying amounts of gold up to 28 percent; also copper, arsenic, antimony, mercury, iron, or platinum. Native silver is much rarer in occurrence than native gold, but is widely distributed in small amounts. It may be primary in its origin but usually is clearly secondary and commonly found in the upper portions of silver-bearing veins associated with other silver minerals.

Argentite (silver glance, sulphide of silver), Ag_2S, is composed of 87.1 percent silver and 12.8 percent sulphur. Crystals are not common; it is generally found disseminated, as a coating, or in arborescent forms. Its hardness is 2 to 2.5; specific gravity, 7.2 to 7.4. It is malleable, perfectly sectile, and takes an impression. On the fresh surface it has a high metallic luster; but on exposure it soon becomes dull and black. The

* Junior mining engineer, California State Division of Mines. Manuscript submitted for publication June 5, 1947.

color is blackish lead-gray, streak shining. Argentite is the most important primary mineral of silver. It occurs at times in large masses and also as microscopic inclusions in galena; and probably in other sulfide ores. It also may occur as a secondary mineral. It is commonly found in veins associated with silver, cobalt, and nickel minerals: proustite, pyrargyrite, amaltite, niccolite, native silver.

Cerargyrite (horn silver, silver chloride), AgCl, contains 75.3 percent silver. The crystals are rare and poorly developed. It is generally found massive and resembling wax or horn; sometimes columnar; often in crusts. It has no cleavage; is highly sectile, cutting easily, and yielding shiny surfaces. It is very soft, hardness, 1 to 1.5; specific gravity, 5.5; luster, resinous to adamantine. The color is pearl gray, grayish green, whitish to colorless, rarely violet blue; on exposure to the light it turns violet, brown, or black. It is transparent to translucent. When rubbed it becomes shiny. It may contain mercury, ferric oxide, or other impurities. It fuses easily on charcoal and yields a globule of silver. Cerargyrite is usually the product of secondary action and is commonly found in the upper parts of silver deposits. The usual associates are the various silver minerals, also galena, limonite, calcite, barite, and cerussite.

Proustite, so named after the French chemist J. L. Proust (1755-1826), is also known as light-ruby silver ore, or light-red silver ore. It has the chemical composition $3Ag_2S.As_2S_3$, and contains 65.4 percent silver. Some proustite contains antimony. Crystals are often small, highly modified, and difficult to interpret. Proustite is generally found massive, disseminated, or in crusts or bands. The cleavage is distinct; fracture conchoidal to uneven. It is a brittle mineral. Its hardness is 2.5; specific gravity 5.5. The luster is brilliant adamantine to dull. The color and streak are scarlet to vermillion. It is transparent to translucent. It fuses on charcoal, emits odors of sulphur and arsenic, and gives a globule of silver. It occurs with pyrargyrite in veins with other silver minerals, galena, and calcite.

Pyrargyrite (ruby-silver, ruby-silver ore, dark ruby-silver ore, dark-red silver ore), $3Ag_2S.Sb_2S_3$, contains 59.9 percent silver and usually also a little arsenic. The crystals resemble those of proustite; they are rarely found. It usually occurs massive, compact, disseminated, or in crusts or bands. The fracture is conchoidal to uneven; hardness 2.5; specific gravity 5.8. The luster is metallic adamantine. The color is red to lead gray; thin splinters in transmitted light are deep red. The streak is cherry to purple red. On charcoal it fuses with spurting to a globule of silver, coats the coal white. Pyrargyrite and proustite are commonly primary minerals which are characteristically found in the upper portions of silver veins. They are commonly associated with other silver minerals, galena, tetrahedrite, and sphalerite. Pyrargyrite is an important ore of silver.

Stephanite (brittle silver ore, black silver), $5Ag_2S.Sb_2S_3$, contains 68.5 percent silver. Crystals are usually short prismatic or tabular. Stephanite is also found massive, compact, and disseminated. The fracture is subconchoidal to uneven. The hardness is 2 to 2.5; specific gravity, 6.3; luster, metallic. Color and streak are iron black. It occurs in many silver deposits associated with other silver minerals, galena, tetrahedrite, and sphalerite. It is usually of primary origin, but is characteristically found in the upper portions of the veins. It was important ore in the Comstock Lode.

Tetrahedrite (gray copper ore, fahlerg, freibergite) is essentially a copper-antimony sulphide. The fundamental formula is probably $3Cu_2S.Sb_2S_3$; the analyses show wide variations. The copper may be in part replaced by silver, iron, zinc, or mercury, and the antimony by arsenic. The ordinary variety contains little or no silver. The argentiferous variety, freibergite, contains 3 to 30 percent silver, and the mercurial variety, schwatzite, contains 6 to 17 percent of mercury. The color of freibergite is usually steel gray, lighter than the ordinary varieties, though sometimes it is iron black. The streak is often reddish. Tetrahedrite is commonly found in copper or silver veins, usually as a primary constituent. It frequently becomes an important ore of copper, or, because of its silver content, an ore of silver.

Polybasite is found in many silver veins, at times in considerable amounts. It is associated with other silver and lead sulfo-salts, with various sulfides and with such nonmetallic minerals as quartz, calcite, dolomite, and barite. Its color is iron black, in thin splinters cherry red; streak is black. Polybasite contains when pure, 75.6 percent silver.

Silver minerals yield malleable metallic globules of silver on charcoal with soda in a reducing flame. On the addition of HCl, nitric-acid solutions of silver minerals give a white curdy precipitate (silver chloride) which changes to violet on exposure to light and is soluble in ammonium hydroxide (NH_4OH).

OCCURRENCE

Several of the more important silver-producing localities in the United States are the Bingham and Tintic districts in Utah; Butte, Montana (from copper ore); Tonopah, Nevada; Coeur d'Alene, Idaho; Aspen, Colorado; Lake Superior copper district (associated with copper). In Canada silver occurs in large deposits, disseminated and in veins, at Cobalt and vicinity in Ontario. There it is associated with niccolite, smaltite, erythrite, annabergite, bismuth, and calcite.

About 80 percent of the silver is obtained as a by-product from gold, nickel, copper, lead, and zinc ores. The four most important sources of silver in the United States which furnish annually about 98 percent of the domestic output are dry or siliceous ores (20 percent), copper ores (30 percent), lead ores (22 percent), and lead-zinc ores (26 percent). The siliceous ores consist mainly of quartz with small amounts of gold and silver. Some of the principal deposits of this type are at Tonopah, Nevada; the Tintic district, Utah; San Juan, Leadville, and Aspen, Colorado; Granite, Jefferson, and Silver Bow Counties, Montana; and in California. The important silver-bearing copper ores are found at Butte, Montana; in the Bingham and Tintic districts, Utah; and at Bisbee and Jerome, Arizona. Deposits of argentiferous galena are mined in the Coeuer D'Alene district, Idaho; the Park City and Tintic districts, Utah; and at Aspen and Leadville, Colorado.

In California, native silver has not been found in any large masses. It is present in many gold and copper districts, and occasionally arborescent crystallizations, wires, and thin sheets are found. It is more common in the silver-lead districts, where it often occurs near the walls of veins and intrusive dikes. Silver mining as an entity does not exist in the state. A relatively small production comes from purely silver ores. In 1946 three-fourths of the silver production in California, amounting to nearly 1,400,000 ounces, came from argentiferous lead and lead-zinc ores. Of

such ores, the Darwin mines in the Coso district and the Columbia Number 2 mine in the Resting Springs district, formerly known as the Tecopa district, Inyo County, were the first and second largest producers respectively. In Inyo County, the Cerro Gordo district was at one time the most productive silver area in the state. The ore consisted of argentiferous galena and cerussite in limestone. Other large silver productions came from zinc-copper ore in the Hornet mine in the Flat Creek district in Shasta County; from zinc ore in the Penn mine in the Capo Seco district, Calaveras County; and from gold-silver ore in the Kelly mine in the Randsburg district, San Bernardino County. The latter is an important gold-, silver-, and tungsten-producing area. Much of the balance of the 1946 silver production came from other base-metal ores, including those of copper and tungsten. Silver has been obtained from 41 counties in California, of these the most important have been Kern, Nevada, San Bernardino, Mono, Napa, Plumas, Placer, Inyo, Butte, Shasta, Amador, and Yuba.

PREPARATION

In the smelting of lead-silver ores, zinc is added to the molten lead and forms an immiscible liquid, which floats and forms a crust. The silver, being more soluble in the zinc than in the lead, is extracted into the upper layer which may then be drawn off and the zinc vaporized from the dissolved silver. Silver is also obtained as a sediment in the electrolytic refining of copper and zinc, and may be recovered from the "mud." Native silver is soluble in mercury, with which it forms an amalgam. Certain ores are treated in this way, the mercury being afterwards removed from the silver by distillation.

Silver is usually recovered by cyanidation from the silver sulfide argentite, from the telluride hessite, and from the arsenious and antimonial minerals proustite, pyrargyrite, and stephanite. The pure sulfide, a gelatinous black precipitate, is obtained as are the sulfides of copper, zinc, and mercury, by treating a solution of a silver salt with hydrogen sulfide or an alkaline sulfide. Silver nitrate is obtained by treating silver with hot, strong nitric acid. The nitrate is soluble and may be crystallized from the solution. Silver chloride, silver bromide and silver iodide are highly insoluble salts prepared by treating solutions of silver nitrate with solutions of chlorides, bromides, or iodides. They are precipitated in highly dispersed form in gelatin for use in photographic plates, film, and paper, and for medical preparations.

Silver chloride and silver bromide dissolve in ammonium hydroxide. The iodide is so highly insoluble that it does not dissolve. Solutions of thiosulfates and of cyanides, however, dissolve even the iodide and the sulfide, which is not affected by ammonia. It is for this reason that sodium thiosulfate, or hypo, is used in photographic fixing baths to dissolve silver salts, while sodium cyanide solutions are used to dissolve sulfide and complex ores of silver in the process of cyaniding. Silver is monovalent in all its compounds and forms colorless ions. It is a very unreactive metal, and its salts are decomposed to the metal when exposed to light or considerable heat.

USES

Native silver is used for coinage, jewelry, and ornamental purposes; also in physical, chemical, and surgical apparatus. Silver used in coinage contains 90.5 percent silver and 7.5 percent copper. Silver is also used

in electroplating tableware and other articles that have as a base either nickel, brass, or britannic metal (tin, antimony, copper, and zinc). Silver is likewise employed in alloys, for jewelry and dental purposes. Dental amalgam consists of an alloy of silver and tin with small amounts of copper and zinc in a powder form, which when used is mixed with mercury. Silver salts are used in photography and in chemistry. The chief uses of silver nitrate are in photography and medicine, in which the chloride, bromide, and iodide of silver are also extensively employed.

Silver is used as an electrodeposited metal coating chiefly because of its efficiency as a carrier of electricity and as a reflector of light rays. Because it is susceptible to tarnishing from sulfur compounds in the air, it is frequently protected by a coating of lacquer when used for reflectors. Silver is also used extensively in solders and brazing alloys. A method of converting sea water into potable drinking water through the use of silver chemicals was developed in relatively recent years; as was a use of silver powder in a ceramic-type composition as a coating on electrically nonconducting materials, such as glass and wood, to give the surface high electrical conductivity and low electrical resistance.

PRICES

The price of silver varies. In 1920 it was about $1.00, in 1932 about 25 cents, and in 1936 about 45 cents, an ounce. The price of domestic silver mined after July 1, 1939 was fixed by Congressional Act at $0.71 per ounce on July 6, 1939. This, the Green Act, expired December 31, 1945. Late in 1946, the price of newly mined domestic silver was fixed by Congressional Act at 91 cents an ounce. Early in January 1947, silver was selling in the open market at 92 cents, and later in the month it was offered at 70 cents an ounce. The U. S. Mints buy silver.

In some ancient states the value of silver appears to have been superior to that of gold. Such was the case in ancient Arabia and the same is said of ancient Germany; as late as the 17th century, silver and gold were valued equally in Japan. Portugal, in 1688, raised the value of gold to 16 times that of silver. Except during a brief period of 40 years, this ratio was maintained in Spanish and British America and the United States until towards the beginning of the 20th century. Spain, in 1775, raised its value to one-fifteenth and a half that of gold for the peninsula, permitting it to remain at one-sixteenth in the colonies. France, whose previous ratio was $14\frac{1}{2}$, adopted the Spanish ratio of $15\frac{1}{2}$ in 1785. These three historical ratios, and the bearing of each upon the others have influenced all legislation on the subject, and, where there was no legislation, have governed the bullion markets for more than two centuries.

REFERENCES

Much has been written on silver. For more complete discussion the following references, some of which give extensive bibliographies, have been selected:

Dana, E. S., and Ford, W. C., A textbook of mineralogy, 4th ed., 1932.

Eshbach, O. W., Handbook of engineering fundamentals, vol. 1, Wiley Engineering Handbook Series, 1926.

Knopf, Adolph, The Darwin silver-lead mining district, California: U. S. Geol. Survey Bull. 580, pp. 1-18, 1913. . . . Mineral resources of Inyo and White Mountain, California: U. S. Geol. Survey Bull. 540, pp. 81-120, 1914.

Kraus, H. K., Hunt, E. H., and Ramsdell, L. S., Mineralogy, 3d ed., 1926.

Ries, H., Economic geology, 7th ed., pp. 573-634, 1939.

Taggart, A. F., Handbook of mineral dressing, 1945.

U. S. Senate, S. Res. 187, Special committee on the investigation of silver. [Contains much valuable information on silver.]

Minerals Yearbook, statistical and economic compilation published yearly by the U. S. Bur. Mines, has a chapter on silver each year.

PUMICE

By W. B. Winston*

OUTLINE OF REPORT

DESCRIPTION

Pumice is a highly vesicular glass produced by the expansion of water vapor within an acid magma at high temperature through relief of pressure as the magma comes to the surface. It may best be described as a glass froth. This froth solidifies and breaks and is expelled from the volcano as pumice and volcanic ash or dust. When examined with a lens, pumice is seen to be composed of a mass of silky glass fibers of a cottony appearance, full of pores, and separated by large holes like a sponge. If drawn out by flowage the fibers are parallel; otherwise they are interwound. In the better-grade deposits these fibers are quite uniform in size and character. The highest grades of pumice are seldom found. Pumice is light colored, white, gray, yellowish, or brownish, rarely red. It sometimes has a somewhat silky luster. The glass of pumice is transparent and colorless and has a hardness of 5.5 to 6, and a density of about 2.5. Apparent density of lump pumice is less than that of water. Pumice is somewhat brittle, and lumps may be flattened or shaped by rubbing; but the sharpness of the grains persists even when pulverized.

Pumice produced from magmas is similar in chemical composition to many igneous rocks such as rhyolite and granite and is composed mainly of silica in the form of complex silicates of aluminum, sodium, potassium, calcium, magnesium, and iron. Material of this nature is relatively inert chemically and does not effervesce in hydrochloric acid as do carbonates, a property sometimes helpful in identification. An analysis of typical pumice would show about the following chemical composition in percent: silica, 72; alumina, 14; potash and soda, 7; lime and magnesia, 2.5; iron oxide, 1; loss upon ignition, 3.5. Individual analyses vary somewhat from these figures and some material contains small quantities of other substances, such as titanium oxide. Pumice from other than an acid magma would contain less silica and more iron oxide, lime, and other bases. Associated with lump pumice is usually a certain amount of volcanic dust and also the incompletely expanded glassy lava or obsidian.

Pumice does not form independent rock masses; it occurs as the upper crust of flows of felsite lava, or in fragments among the explosive materials ejected by volcanoes. These fragments vary in size from blocks containing several cubic feet to grains the size of sand. The completely shattered or disrupted lava is formed of small shards or bubble fragments of volcanic glass and is the volcanic ash or dust of the volcanologist (commercially pumicite). On account of its light, porous nature, and its content of sealed glass cells, lump pumice floats almost indefinitely on

---

* Junior mining engineer, California State Division of Mines. Manuscript submitted for publication June 10, 1947.

water, and the material ejected by volcanoes near or in the sea is borne by currents all over the world. As it sinks when thoroughly saturated, it is also found very widely diffused over the ocean-bed even at points far removed from volcanic vents.

Although all magmas, whatever their chemical composition, at times and under proper conditions form pumiceous rocks, typical pumice is most characteristic of the felsitic rocks (acid lavas), whereas basaltic pumices (basic lavas) are of local development and of small importance. These pass, especially on the upper surface of basalt flows, and in the material thrown out by volcanoes, into more or less glassy, partly stony, dark or reddish, loosely compacted, spongy, cindery or slag-like modifications known as volcanic scoria.

Pumice, scoria, volcanic tuff, volcanic breccia, and volcanic cinders are the only common rocks light and strong enough to be classed as natural lightweight aggregates. Of these, pumice is the most important. All lightweight aggregates impart essentially the same characteristics in varying degrees to the finished concrete in which they are incorporated. Light weight, nailability, ease of cutting or channelling, and adequate heat and sound insulation in the finished work are the principal desirable properties.

The term pumice has been employed loosely to include a variety of cellular, glassy rocks, products of volcanic activity and composed preponderantly of silica and alumina. In California, the term is incorrectly used locally to include volcanic scoria, pumicite, or volcanic dust, and other cellular and sometimes amygdaloidal lavas of light density due to structure. Pumicite is a term most generally applied to the fine-powdered volcanic ash of the Kansas-Nebraska region and but seldom to the coarser sandy varieties common in the Rocky Mountains and Pacific states. It looks to the unaided eye like very fine closely packed glassy sand. In the purer deposits the color is white to light or bluish gray; impurities may cause a yellow, brown, or red stain. Minute sparkles are readily noted in bright sunlight. Magnified particles show marked angularity resembling powered glass. In texture, pumicite varies from loosely consolidated particles to flint-like material with the individual grains lightly cemented together. It has been copyrighted as a trade name.

Volcanic tuff is generally a fine-grained rock, light in weight, and often of a chalky consistency, sometimes dense and compact. It breaks into small chips. The color is usually light, white, pink, pale brown, gray or yellow, sometimes passing into darker shades. The more compact varieties may be easily mistaken for felsite lavas; it is quite possible in some cases that they cannot be distinguished from the lavas megascopically, but generally attentive examination with a good lens will reveal angular particles of quartz, feldspar, and often other minerals in them, and possibly small fragments of other rocks. When breathed upon, they usually give off a strong argillaceous odor. When not too compact, they have a tough feel and yield a gritty dust when strongly rubbed between the fingers.

Volcanic breccia has a base or cement of tuff, more or less completely filled with lapilli of angular shapes, and these are often mingled with larger bombs and masses which are apt to be rounded. Interspersed with these are apt to be fragments of other rocks. The breccias have therefore a strongly conglomerative aspect. The colors of these breccias are variable; browns, reds and chocolate are common, along with lighter tones

depending partly on the state of oxidation of the iron-bearing compounds and partly on the nature of the magma, whether felsitic (which tends to lighter colors), or basaltic (which produces darker ones). Volcanic cinders are rough fragments of vesicular lava either erupted from a volcano or formed by shattering of the crust of a lava flow through rapid cooling.

Recently a new industrial product has been made using perlite as the raw rock for thermal expansion into pumice-like material, which can fill all the known uses of pumice and volcanic ash and has some advantages over natural pumice. Since the material is any siliceous lava containing dissolved water or gases in sufficient amount to expand into bubbles when the material is quickly heated to a suitable point in the softening range, it may be concluded that, as an industrial mineral, the definition of "perlite" must be expanded beyond the rather rare form of acid lava given that name by the petrologists to include any rock of the obsidian family which upon proper heating will expand to 10 to 20 times its former volume. Natural perlite is a peculiar variety of glassy rock composed of small spheroids, usually varying in size from small shot to peas. Generally of a gray to blue-gray color, rarely red, it has a soft, pearl, or wax-like luster and resembles enamel. It is produced only by felsitic magmas, especially by those high in silica. It does not occur in basaltic glasses.

In tables 1-4, chemical compositions of various volcanic ejecta are given. These comprise the Medicine Lake Highland basalts, andesites, dacites, rhyolites (perlitic rhyolite, vesicular rhyolite, and obsidian), and pumice ejecta from Glass Mountain and from Crater Lake region in eastern Oregon. The analyses given are representative of similar rock types in other localities.

OCCURRENCE

Basic lava behaves differently from acid lava. It softens at a comparatively low heat and is characteristically liquid down to its freezing point and will therefore usually flow quietly from a volcano. Deposits of pumiceous basalts, however, commonly yellow or brown in color, do occur in the Sandwich Islands. Acid lavas melt at relatively high temperatures and are likely to be quite viscous when even slightly chilled. At temperatures which would have little effect upon a basic lava, they are apt to harden or cease to flow readily. Such stoppages in the volcanic vent cause enormous pressures to build up until the force becomes sufficiently powerful to blow out the plugging material with such explosive violence as to hurl great masses of material out from the volcano. During volcanic activity different conditions favor the formation of pumice. Required are usually a molten acid lava, highly impregnated with gases, with conditions of temperature, pressure, and extrusion such as to permit gas to expand in the hot lava, forming bubbles or threads and fibers with thin glasslike walls between the cells. Vesicles must not expand to point of disruption, and the walls must harden rapidly enough to prevent collapse upon any release of pressure and to prevent the formation of mineral crystals. Deposits of pumice are always located near centers of volcanic activity. Some occurrences are massive and capable of yielding pumice in lump form; others are quite loosely consolidated, being in the form of sand or gravel. Slightly different conditions, greater pressure and explo-

9—76940

Table 1. Chemical analyses of basalts

Constituent		1	2	3	4	5	6
Silica	SiO_2	47.10	48.98	49.66	51.46	54.56	55.46
Alumina	Al_2O_3	18.52	18.92	19.79	17.69	17.52	17.70
Titanic acid	TiO_2	0.90	1.16	1.12	1.25	1.28	0.68
Ferric oxide	Fe_2O_3	Tr.	2.22	4.80	1.37	8.70	1.58
Ferrous oxide	FeO	7.91	7.12	5.40	9.05	0.32	5.12
Manganese oxide	MnO	Tr.	0.09	0.06	0.18	0.04	0.08
Magnesium oxide	MgO	10.89	7.42	4.16	5.13	4.34	5.86
Calcium oxide	CaO	11.98	10.04	10.90	8.92	8.14	8.12
Sodium oxide	Na_2O	2.33	3.04	3.37	3.37	3.94	3.00
Potash	K_2O	Tr.	0.44	0.72	0.77	0.90	1.58
Water +	H_2O +	0.10	0.34	0.18	0.44	0.10	0.50
Water —	H_2O —	0.18	0.05	--	0.30	0.05	0.01
Phosphorus pentoxide	P_2O_5	0.09	0.14	0.17	0.14	0.22	nil.
		100.00	99.96	100.33	100.07	100.11	99.69

Medicine Lake Highland:

1. Basalt, subophitic; Warner basalt, Lairds Ranch.
2. Basalt, subophitic; Modoc basalt near Burnt lava flow.
3. Basalt, porphyritic; Lake basalt, near Medicine Lake.
4. Basalt, intersertal; Modoc basalt.
5. Basalt, intergranular; Modoc basalt, cinder cone northwest of Medicine Lake.
6. Basalt, porphyritic; Modoc basalt, Burnt lava flow.

Table 2. Chemical analyses of andesites and dacites

		Andesites 7	8	9	Dacites 10	11
	SiO_2	58.44	59.98	65.70	67.70	68.44
	Al_2O_3	16.96	17.28	16.34	16.32	15.44
	TiO_2	0.92	1.20	0.75	0.30	0.49
	Fe_2O_3	1.51	2.56	0.70	0.27	1.17
	FeO	6.22	4.88	4.07	3.20	2.08
	MnO	0.09	0.15	0.15	Tr.	0.04
	MgO	3.36	2.10	1.78	1.25	1.46
	CaO	6.60	4.72	3.70	3.35	3.47
	Na_2O	3.43	4.92	4.00	3.89	3.72
	K_2O	1.47	1.68	2.83	3.22	3.32
	H_2O+	Nil.	0.21	Nil.	0.22	0.31
	H_2O—	0.50	N.d.	Nil.	0.05	0.08
	P_2O_5	0.21	0.44	0.03	0.06	0.21
Sulfur	S	0.11	N.d.	Nil.	0.20	0.03
Chlorine	Cl	--	--	--	--	0.03
Barium oxide	BaO	--	--	--	--	0.06
		99.82	100.12	100.05	100.03	100.35

Medicine Lake Highland:

7. Platy olivine andesite, near south end of Callahan lava flow.
8. Platy andesite, surface vesicular phase, south of Medicine Lake.
9. Dacite, porphyritic, northeastern tongue of rhyolite-dacite composite flow.
10. Dacite, porphyritic, Medicine flow.
11. Oxidized surface phase, Medicine flow.

Table 3. Chemical analyses of rhyolites

	12	13	14	15	16
SiO_2	71.32	71.50	72.40	73.59	74.10
Al_2O_3	14.70	14.66	14.26	14.03	13.33
TiO_2	0.22	0.22	0.25	0.31	0.20
Fe_2O_3	0.69	0.33	0.81	0.42	tr.
FeO	2.02	2.28	2.03	1.43	1.68
MnO	nil.	tr.	nil.	0.02	tr.
MgO	0.56	0.44	0.36	0.36	0.38
CaO	2.52	1.50	1.55	1.38	1.45
Na_2O	4.12	4.53	3.85	4.04	3.86
K_2O	3.46	4.07	4.07	4.34	4.50
H_2O+	0.42	0.20	0.40	0.12	0.29
H_2O-	0.09	tr.	nil.	0.06	0.05
P_2O_5	tr.	nil.	tr.	0.09	nil.
S	--	0.21	tr.	0.02	0.22
Cl	--	--	--	0.03	--
	100.12	99.94	99.98	100.24	100.06

Medicine Lake Highland:

12. Perlitic rhyolite, 1 mile south of summit of Mount Hoffman.
13. Obsidian, older rhyolite, north slope, Medicine Lake Highland.
14. Finely vesicular rhyolite glass from summit of Glass Mountain.
15. Obsidian from Little Glass Mountain.
16. Obsidian, older rhyolite, south slope, Medicine Lake Highland.

Table 4. Chemical analyses of pumice

	17	18	19	20	21
SiO_2	72.75	73.10	71.30	69.50	68.56
Al_2O_3	13.83	14.10	13.76	15.18	14.22
TiO_2	0.25	0.25	0.20	.41	.58
Fe_2O_3	0.78	0.57	0.47	1.24	1.42
FeO	1.61	1.86	2.02	1.42	1.49
MnO	nil.	nil.	tr.	.03	.03
MgO	0.62	0.35	0.42	.83	.83
CaO	1.80	1.50	1.66	2.08	2.35
Na_2O	3.80	3.80	3.85	4.78	5.18
K_2O	4.00	4.10	3.88	2.18	2.47
H_2O+	0.30	0.40	1.95	--	--
H_2O-	0.20	nil.	0.35	--	--
P_2O_5	tr.	tr.	0.03	.21	.10
S	tr.	tr.	0.21	--	--
H_2O	--	--	--	2.51	3.32
	99.94	100.03	100.10	100.37	100.55

17. Pumice ejecta from cone remnant, south of Glass Mountain, Medicine Lake Highland.
18. Pumice from surface of obsidian flow, Glass Mountain, Medicine Lake Highland.
19. Rhyolitic pumice from Pumice Stone Mountain, Medicine Lake Highland.
20. Lump pumice, Crater Lake, Oregon.
21. Lump pumice near Chemult, Klamath Marsh, Oregon.

Nos. 1, 2, 3, 4, 5, 6, 8, 10, 11, 13, 15, 16, and 19, quoted from Powers, H. A., The American Mineralogist, vol. 17, July 1932.

Nos. 7, 9, 12, 14, 17, 18, quoted from Anderson, C. A., Univ. California, Dept. Geol. Sci. Bull., vol. 25, 1941.

Nos. 20 and 21 quoted from Moore, B. N., U. S. Geol. Survey Bull. 875, pp. 157 and 159, 1937.

Nos. 1, 4, 7, 9, 10, 12, 13, 14, 16, 17, 18, 19, Herdsman, analyst.

Nos. 2, 3, 5, 6, 8, Gonyer analyst.

Nos. 11 and 15, Shepherd, analyst.

Nos. 20 and 21, Fahey, analyst.

sive force, may produce volcanic dust or pumicite. In such eruptions, a portion of the lava may be spumed into the air in very fine particles, not unlike pulverized glass, accompanied by water vapor, gases, and fragmental volcanic rocks. Much of the dustlike material is borne hundreds and even thousands of miles by air currents.

By general usage, for the sake of convenience, the following sizes of volcanic ejecta are roughly distinguished: pieces the size of an apple or larger are called bombs; those the size of a nut are termed lapilli; those the size of small peas or shot, ashes; the finest is known as volcanic dust (commercially pumicite). Sometimes the bombs, lapilli, etc., are sharply angular and sometimes smoothly rounded—a form caused by the grinding and attrition of the pieces upon one another in the upward rush from the volcanic throat. They should be distinguished from water-rounded bombs. The ashes and lapilli which usually make up the greater part of the material are frequently spoken of as volcanic cinders and cones composed of them are called cinder cones. When the rock is composed entirely of the finer particles, dust and ash, it is called volcanic tuff; when this is mixed with the coarser bombs and lapilli, it is termed volcanic agglomerate or volcanic breccia.

Commercial deposits of pumice occur in California and many other western states. Much of the material is associated with tuffs of all kinds, which include the indurated pumicite, scoriae, and other materials peculiar to volcanic formations. In California the more important sources of pumice are in Siskiyou, Modoc, Napa, Madera, Inyo, and Mono Counties. Formerly, considerable production came from the vicinity of Salton Sea in Imperial County.

In Mono County extensive deposits of a coarsely granular pumice occur in the volcanic tableland on the west side of Hammil and Benton Valleys. The principal deposits extend from Benton south to the Inyo County line. Other deposits of importance exist on the west slope of White Mountains from Sacramento Canyon to Inyo County line. The material mined at Blind Springs Hill is described as pure white to gray lumps ranging in size from that of a pea to that of a walnut. The bed is 20 feet thick and covered in places by 5 to 25 feet of red tuff overburden. Other occurrences are of a similar character.

The pumice mined in Madera County, near Friant, Fresno County, is described as brownish in color, ranging in size from coarse sand and small pellets to material 1 inch in diameter, and occurring in beds 15 to 20 feet thick, covered by 1 to 4 feet of soil. The material lies on a layer of fine-grained pumice of the same color about a foot thick, under which is a bed of whitish-gray, fine, wind-blown volcanic ash, 20 or more feet thick.

In Napa County and vicinity there is a wide distribution of acidic volcanic rocks which show many variations in texture.

Considerable pumice mining is now being carried on in Siskiyou and Modoc Counties, where pumice deposits are being worked on the northern and eastern edges of the glass flow surrounding Glass Mountain, located on the Medicine Lake Highland 35 miles east of Mount Shasta. The pumice occurs in horizontal beds some 14 feet thick at the edge of the glass flow, grading to approximately 2½ feet a mile distant. The beds lie above a brown lava which has weathered to a soft reddish-brown sandy loam, 12 to 14 inches deep in places. The pumice is fragmental, white to gray in color, and has an average maximum size of about 1 inch. Few

pieces are over 2 inches. The lavas of the Medicine Lake Highland represent a well-differentiated series from basalts to rhyolites with gradations from one rock type to another except from andesite to dacite. Holocrystalline basalts are the most basic lavas and rhyolitic obsidians are the most silicic. With increasing silica content the lavas become porphyritic with or without a glass base. The porphyritic basalts merge into andesites. Many of the true andesites are slightly porphyritic and possess a platy structure. Glass is absent except in the surface vesicular phases. The dacites are porphyritic with cryptocrystalline ground mass. They grade into porphyritic rocks with perlitic glass ground mass which have been classified as rhyolites, and these merge into essentially rhyolite obsidian. The geology of eastern Siskiyou, eastern Shasta, and most of Modoc and Lassen Counties is favorable to the finding of pumice deposits.

Other deposits of ''lightweight volcanic material'' described as suitable for aggregate, are reported to occur in Plumas, Nevada, Sonoma, San Luis Obispo, Santa Barbara, and Ventura Counties. Comparatively few pumice deposits in the state have been worked. Some have been investigated, others are known but remain in their natural condition, and probably other occurrences will be found if search is made. Prospecting for pumice in the Pacific states has not been difficult since many of the deposits are not covered by overburden. Large tonnages may be blocked out with little expense because of the regularity of bedding of the deposits interbedded with other sediments.

The production of pumice in California in 1945 came from four properties in Siskiyou County, two each in Contra Costa, Inyo, Mono, and Modoc Counties, and one each in Madera and Napa Counties. The total production amounted to 74,505 tons, valued at $309,277. The 1946 production came from five properties in Madera County, four in Siskiyou, three each in Inyo and Modoc Counties, two each in Contra Costa, Mono, and Napa, and one each in Calaveras and Kern Counties. The total production amounted to 109,191 tons with a value of $540,811 at the property. Most of the United States production of pumice aggregate comes from operations in California. Of the pumice imported into this country, more than 90 percent comes from the high-grade pumice deposit on the island of Lipari in Italy.

PREPARATION

Pumice is the oldest known lightweight aggregate. During the great Roman building period, over 2000 years ago, fragments of pumice 3 to 6 inches large were used as aggregate to reduce dead weight in the construction of many of the great domes. Little is known of its use from that time until shortly after the middle of the last century when pumice-concrete was introduced in the Nette and Brohl Valleys in Germany. Until recently, operators of pumice deposits in the United States regarded sales of the material for aggregate purposes merely as an adjunct to the operations necessary to obtain abrasive-grade pumice, and no attempt was made to develop the aggregate market. So far, nearly all of the domestic production of pumice aggregate has been from operations in California, where the first large-scale use of pumice for concrete aggregate in this country began in 1925 near Napa.

In California, in Napa County, the quarried pumice is passed through a hammer mill and wet screened to two aggregate sizes, minus 7/16- to plus $\frac{1}{8}$-inch and minus $\frac{1}{8}$-inch to plus 50-mesh. Concrete for complete line

of wall, floor, and roof units averages 80 pounds per cubic foot. A standard 8- by 8- by 16-inch masonry unit, hollow block, weighs approximately 30 pounds. All units sold under the trade name "basalite" have the desirable properties given by the lightweight mixture. Acoustical units and slabs are made with pumice concrete weighing approximately 50 pounds per cubic foot. The weights of some Napa County aggregate materials in pounds per cubic foot are as follows: Volcanic cinder, rhyolite tuff, 125; trachyte tuff, 86; semi-crystalline tuff, 120; porous pumice, 25.

In the Medicine Lake section in Siskiyou and Modoc Counties, mining consists of stripping the flat surface of the beds free of shrubbery and forest litter with a bulldozer for a given area. Large dump trucks are then loaded by various mechanical means and from bins filled by bulldozers. Pumice is hauled to nearest railroad sidings. Some of it is made into building blocks at plants near Tionesta, and a small amount goes by trucks to Klamath Falls processing plants, but the bulk of it is shipped in open gondola cars to west-coast cities. The railroad classifies the material as pumice scoria and has set a weight equivalent of 1,000 pounds to a cubic yard for freight-schedule purposes. The pumice when mined weighs about 1,300 pounds per cubic yard and contains 20 to 25 percent moisture. The fine vesicular lump pumice aggregate weighs 35 pounds per cubic foot. Concrete made with the pumice aggregate weighs 70 to 75 pounds per cubic foot when mixed one part cement, two parts pumice sand, and four parts coarse aggregate. The pumice prepared for use as building-block aggregate is reduced to minus $\frac{1}{4}$-inch mesh and mixed with cement in a 9 or 10 to 1 ratio in various type mixers. Vibrating-type block machines of 4- to 6-block capacity are filled by hoeing the mixed material into them, after which the blocks are sun dried 14 days before shipping.

In Mono Couny near Tom on the west side of Hammil Valley, pumice is quarried from a hill deposit. The quartz sand, with which the pumice occurs mixed, is removed by passing the crude material over dry concentrating tables. Pumice from tables is screened to desired sizes and oversize is passed through a system of roll crushers. The pumice for use with gypsum for plaster work is dried in rotary driers and packed in burlap sacks of 80 pounds each for shipping. Virtually all sizes of pumice from $\frac{1}{4}$-inch to minus 60-mesh are produced. Most of the product is used in acoustic plaster and is sized to minus 8- and plus 30-mesh. Sizes plus 8- and minus 30-mesh are used for concrete work. The weight of white pumice aggregate, fine to walnut size, is 25 to 35 pounds per cubic foot, and that of gray material, same size, 40 to 50 pounds per cubic foot. In Madera County, most of the deposits near Friant are worked by open cut. Pebble pumice makes concrete weighing 90 pounds per cubic foot and is used by block manufacturers. The weight of the dry raw pumice is 1700 pounds to a cubic yard. Weights of volcanic aggregate material from other counties in pounds per cubic foot are as follows: Nevada, red volcanic cinder 40; Sonoma, semi-crystalline breccia 139; San Luis Obispo, fine-grained rhyolite tuffs 76; porous tuffs 80 to 88; Inyo, white and fine pumice, maximum size 2 inches, 25 to 35, gray pumice 30 to 40, volcanic cinder 77.

Test and specifications for lump pumice and other pumice materials are indefinite. For abrasive purposes, such material should be free from unexpanded glass or mineral grains and should consist of small even-walled cells. A high-grade lump pumice must consist of sufficiently large lumps to trim to hand-size blocks. It must have a very uniform texture and contain no stony or glassy blebs. As the abrasive action of pumice

depends on the cutting action of the thin glass walls, it is imperative that no hard grains be present which would gouge or scratch the surface being polished. The greater part of the lump material is ground to powder and relatively little is used as an abrasive in the lump form. An elaborate system of grades has been established for the ground pumice, and some producers sell it with specified abrasive efficiencies. Users of ground pumice find that it is not possible to substitute the natural volcanic dust for their uses.

The regular expected qualities of a lightweight aggregate are several: Material should be well graded as to size, should be sufficiently firm to stand handling without size breakdown; individual pieces should possess some compressive strength; material should bond well with the cement and be inert chemically; it should remain unaffected by all forms of weathering and should be as light as possible without impairment of the other qualities; the mix should not weigh more than about 75 percent of the weight of ordinary concrete; lightweight aggregates should weigh less than 50 pounds per cubic foot. A table of lightweight aggregates for concrete issued by the Construction Branch, National Housing Agency, gives the aggregate weight in pounds per cubic foot for gravel, 120; sand, 90 to 100; crushed stone, 100; and pumice, 30 to 60. Weight in pounds per cubic foot of concrete made from various aggregates is gravel, 150; sand, 150; crushed stone, 145; and for pumice, 60 to 90.

The pumice imported for domestic abrasive trade consumption is mostly milled in the East. American-ground Italian pumice is prepared from small pieces of high-grade material (pezzame) shipped to this country in bags. It is carefully crushed, screened, dried, and finally bolted through Swiss silk.

USES

Pumice has many uses. The very finest air-floated powder of ground pumice (grade FFFF) is used for extremely fine abrasive work and in certain dental preparations. Much of the finest grades of ground pumice are used for finishing silverware, watch cases, and other kinds of metal ware, and in the electroplating industry for cleansing, scouring, and polishing; for finishing auto bodies; for certain kinds of soap; for glass cutting and beveling; for piano finishing; for rough rubbing; and in mechanics' soap, for coarse rubbing of hard materials. Sizes from sand to that of a pea are used in tumbling barrels. Lump pumice is used for hand rubbing of stone such as marble; for rubbing down paint surfaces; for finishing automobile bodies; for finishing leather; in lithographic work; and to a considerable extent in the electroplating industry for cleaning buffing wheels. A small quantity of the highest-grade material is used as a toilet article. Pumice has also been used in the manufacture of vinegar as a porous packing material for the generators which convert dilute alcohol into acetic acid; in the chemical industry as a filter medium, and as a catalyst carrier. Much is used as a soil modifier—it "lightens" heavy soils, increases porosity (to water) and increases water retention of the soil. Considerable quantities are used for chicken litter.

Most of the pumice produced in California is used in manufacture of acoustic plasters and as a lightweight aggregate in concrete. The purpose of acoustic plaster is to absorb sound waves striking the walls with as little reflection as possible. Pumice has been used in place of sand for preparing acoustic plasters and has given satisfactory results. A

considerable field exists for further development of both acoustic and sound-deadening material. The largest outlet for lightweight aggregates is in the manufacture of all types of precast building units. Some of the advantages claimed for pumice aggregate materials are lightness, heat- and sound-insulating qualities, incombustibility, artistic rough surface if laid up without coating, and a surface to which plaster readly adheres if coatings are used. In poured-concrete construction, pumice aggregates have been found satisfactory for use in floors of drawbridges, long bridge spans, and large buildings, and as fire-resistant covering or curtain panels surrounding the load-bearing, structural-steel frame of buildings.

MARKETING

The average value for California pumiceous material for 1946 was reported by producers at $6.00 per ton. In Siskiyou County raw pumice aggregate sells for $3.00 per cubic yard on cars at Tionesta. Material ground through $\frac{1}{4}$-inch mesh sells for $3.75 per cubic yard on cars.

BIBLIOGRAPHY

The references given below have been the principal sources of the data contained in this paper. Some of these publications give extensive bibliographies.

1. Anderson, C. A., Volcanoes of the Medicine Lake Highlands, California: Univ. Calif., Dept. Geol. Sci. Bull., vol. 25, pp. 347-422, 1941.

2. Allison, I. S., Pumice beds at Summer Lake, Oregon: Geol. Soc. America, vol. 56, pp. 798-808, 1945.

3. Benjovsky, T. D., and Clippinger, D. M., Natural lightweight building-block materials of New Mexico: New Mexico Bur. Mines and Nat. Res., Circ. 10, Oct. 1945. [Pumiceous scoria concrete.]

4. Hatmaker, Paul, Pumice and pumicite: U. S. Bur. Mines Inf. Circ. 6560, 23 pp., 1932.

5. Pirson, L. V., Description of igneous rocks: Rocks and Rock Minerals, pp. 260-274, 1915. [Good illustrations of pumice and scoria.]

6. Powers, H. A., The lavas of the Modoc Lava-Bed quadrangle, California: Am. Mineralogist, vol. 17, pp. 253-294, 1922.

7. Moore, B. N., Lump pumice in eastern Oregon: U. S. Geol. Survey Bull. 875, pp. 149-175, 1937.

8. Moyer, E. T., lightweight aggregates for concrete: U. S. Bur. Mines Inf. Circ. 7195, 25 pp., 1942.

9. Roelfe, G. D., California pumice made into concrete building units Pumatile: Rock Products, Aug. 1927.

10. Wilson, C. D., Properties of assorted lightweight materials: U. S. Dept. Commerce Publication PB-25373.

Various reports of the California State Division of Mines describe briefly the pumice deposits in California. These reports are listed below. For production statistics and a list of pumice producers, the annual *California Mineral Production and Directory of Mineral Producers* bulletins of the Division of Mines may be consulted.

1. Tucker, W. Burling, Imperial County: California Min. Bur. Rept. 17, pp. 267-272, 1921. [Pumice, pp. 270-271: Brand and Stevens deposit.]

2. Logan, Clarence A., Sacramento field division—Siskiyou County: California Min. Bur. Rept. 21, pp. 413-498, 1925. [Pumice, p. 495.]

3. Tucker, W. Burling, Los Angeles field division—Imperial County: California Min. Bur. Rept. 22, pp. 248-285, 1926. [Pumice, p. 280: California deposit, Brand and Stevens deposit.]

4. Tucker, W. Burling, Los Angeles field division—Inyo County: California Min. Bur. Rept. 22, pp. 453-530, 1926. [Pumice and volcanic ash, pp. 520-522: Coso Mountain pumice deposit, Hunter Canyon pumice deposit, Fairbanks volcanic ash deposits, Glendening volcanic ash deposit.]

5. Tucker, W. Burling, Los Angeles field division—Mono County; California Min. Bur. Rept. 23, pp. 374-406, 1927. [Pumice and volcanic ash, pp. 403-404: California Quarries pumice deposit, Blind Springs Hill pumice deposits, Sacramento Canyon pumice deposit, Yellow Jacket Canyon pumice deposits.]

6. Erwin, Homer D., Geology and mineral resources of northeastern Madera County, California: California Div. Mines Rept. 30, pp. 7-78, 1934. [Pumice, p. 51.]

7. Averill, Charles Volney, Mines and mineral resources of Siskiyou County: California Div. Mines Rept. 31, pp. 255-338, 1935. [Pumice, p. 335: Johnson deposit, Mt. Hoffman claims.]

8. Tucker, W. Burling, and Sampson, R. J., Mineral resources of Inyo County: California Div. Mines Rept. 34, pp. 368-500, 1938. [Pumice and volcanic ash, pp. 484-486: Coso Mountain deposit, Hidecker (Hunter Canyon) deposit, Little Lake deposit, Pumice Product Company's deposit, Shoshone deposit, Sierra Minerals Inc. deposit, Tripoli deposit, Virginia (Glendenning) deposit.]

INDEX TO VOLUME 43

Chapter 1, January 1947 *Journal*, includes pp. 1-76.
Chapter 2, April 1947 *Journal*, includes pp. 77-162.
Chapter 3, July 1947 *Journal*, includes pp. 163-358.
Chapter 4, October 1947 *Journal*, includes pp. 359-502.

A

B

C

D

E

F

G

H

L

M

P

S

T

Y

Z

O

76940 8-47 2M

LIST OF PRINCIPAL MINERAL DEPOSITS IN SISKIYOU COUNTY, CALIFORNIA

ASBESTOS

1 Chamberlain (Burns) Ranch sec 16 17 T 42 N R 6 W M D
2 C C Cady prospect, T 45 N, R 7 W M D
3 Shasta View prospect, sec 8 T 41 N, R 5 W M D

CHROMITE

4 Barkhouse and Whiskey Boy claims sec 11 T 46 N R 12 W M D
5 Black Crow and Black Hawk claims (Eldridge) sec 20, T 38 N R 11 W, M D
6 Browne Ranch sec 1, T 41 N R 9 W M D
7 Burton Ranch, sec 24 T 44 N, R 8 W, M D
8 Coggins mine sec 35, T 39 N R 4 W M D
9 Constable and Foster claims sec 1, T 41 N R 7 W M D
10 Costello mine, sec 24 T 44 N R 8 W, M D
11 Cyclone Gap (Mammoth) mine S ½ sec 15 T 17 N R 5 E H
12 Doe Creek W ½ sec 32 T 17 N R 5 E H
13 Dry Gulch mine sec 16, T 38 N, R 11 W, M D
14 Fairview chrome mine secs 27, 34, T 46 N R 11 W, M D
15 Flederman lease sec 9 T 44 N R 7 W M D
16 Genesee (Hayden) claim sec 35 T 42 N R 7 W M D
17 Ladd (Red Mountain, Do bear) mine sec 15 T 46 N R 11 W, M D
18 Lady Gay sec 30 T 45 N, R 10 W M D
19 Lambert (Peg Leg) chrome mine, sec 25, T 44 N, R 8 W M D
20 McGuffy Creek deposits sec 25 T 45 N R 11 W M D
21 Seiad Valley chromite deposit secs 7 17 18 19 20, T 47 N R 11 W, M D
22 Simas Ranch sec 35, T 44 N R 8 W M D
23 Snowy Ledge chrome mine sec 21 T 48 N R 9 W M D
24 Wild and Johnson deposit, N ½ sec 19 T 42 N R 8 W, M D

COAL

25 Cooley Ranch, T 46 N, R 5 W

COPPER

26 Big Blue claims sec 36 T 40 N R 9 W, M D
27 Blue Ledge mine, sec 3, T 47 N R 11 W sec 34 T 48 N, R 11 W, M D
28 Copper Creek (Blue Bell) group, sec 31 T 16 N, R 8 E, H
29 Copper King sec 20 T 40 N R 7 W M D
30 Copper Mountain group sec 36, T 14 N R 5 E H
31 Facey mine SW ¼ sec 23, T 41 N, R 9 W M D
32 Gray Eagle (Dakin) mine, secs 13 14 23, T 17 N R 7 E, M D
33 Mammon group sec 14 T 41 N R 7 W M D
34 Polar Bar claim sec 12, T 40 N R 8 W
35 Preston Peak mine sec 22, T 17 N, R 5 E, H
36 Yellow Butte mine, sec 25 T 43 N, R 4 W, M D

GOLD

37 Abe Lincoln No 2 placer, sec 6, T 46 N, R 12 W M D
38 Anna Johnson and Surprise, sec 10, T 39 N, R 11 W, M D
39 Autumn mine, sec 2 T 40 N, R 9 W M D
40 Beaudry placer sec 35, T 40 N, R 9 W M D
41 Beaver Dredging Co sec 30, T 47 N R 8 W, M D
42 Bend mine sec 5 T 39 N R 12 W M D
43 Black Bear quartz mine, sec 13, T 39 N, R 12 W, secs 7, 18, T 39 N R 11 W, M D
44 Buzzard Hill Mine Inc secs 4, 5 T 15 N R 7 E sec 32, T 15 N, R 7 E H.
45 C & E Dredging Co sec 30 T 45 N, R 8 W, M D
46 California American Mining Co sec 31 T 47 N R 6 W M D
47 Cal Oro Dredging Company Gordello dredge secs 14, 22 23, T 45 N, R 7 W, M D.
48 Chambers hydraulic mine sec 15 T 38 N R 11 W M D
49 Chenoweth Brothers dredge sec 27 T 46 N R 11 W M D
50 Cherry Hill mine sec 27 T 45 N R 8 W M D
51 China Point placer secs 5 6, 7 8 T 16 N R 8 E, M D
52 Classic Hill mine sec 36, T 18 N, R 6 E H
53 Cor... quartz mine sec 11 T 37 N R 11 W M D
54 Corbett gold (Trust Buster) mine, secs 3, 10, T 47 N R 8 W, M D
55 Crouch mine, sec 11, T 45 N, R 8 W M D
56 Crumpton placer sec 2 T 16 N, R 7 E H
57 Crystal Creek Mining Co sec 27, T 45 N R 8 W, M D
58 Curran mine sec 25 T 40 N R 12 W M D
59 Dania mine sec 7, T 46 N R 7 W, M D
60 Donnelly placer sec 7, T 16 N R 8 E H
61 Eliza group secs 4 5 8 9, T 45 N R 8 W, M D
62 Enterprise placer sec 21, T 45 N R 10 W M D
63 Etna Gold Dredging Co sec 13, T 40 N R 9 W M D
64 Farnsworth hydraulic mine sec 34 ? T 38 N R 11 W M D
65 Fort Goff hydraulic mine sec 31, T 47 N R 12 W M D
66 French Gulch Gold Dredging Co secs 13, 14 T 44 N, R 9 W, M D
67 Gibraltar mine sec 13 T 43 N R 10 W M D
68 Gold Bar mine sec 2 T 45 N R 7 W M D
69 Gold Mountain group sec 2, T 41 N R 7 W sec 35 T 42 N R 7 W, M D
70 Gold Reef mine sec 34, T 43 N R 10 W M D
71 Gold Ventures Ltd sec 4, T 46 N R 12 W sec 32 T 47 N, R 12 W, M D
72 Golden Eagle mine sec 11 T 44 N R 9 W M D
73 Golden Rule mine sec 26 T 48 N R 8 W M D
74 Golden Wonder secs 27 28 34 T 45 N R 8 W M D
75 Hansen group secs 1 12 T 9 N R 7 E H
76 Hegler (Oregon) mine sec 3, T 45 N, R 8 W M D
77 Hogan mine sec 32, T 41 N R 10 W M D
78 Homestead placer mine sec 2 T 40 N R 9 W, M D
79 Horton Gulch secs 29 30 T 38 N R 11 W M D
80 Humming Bug Mine Inc sec 17 T 45 N R 7 W M D
81 Ida May mine sec 15 T 39 N R 11 W M D
82 Indian Bottoms Mining Co secs 16 20 21 T 11 N R 7 E H
83 Joubert placer secs 4 8 9 T 39 N R 11 W M D
84 Judge hydraulic mine sec 33 T 40 N R 11 W M D
85 Kanaka Hill hydraulic mine, secs 27 28 34 T 16 N R 7 E H
86 K C mine sec 6 T 45 N R 9 W sec 1 T 45 N R 10 W M D
87 Kate May group secs 13 24 T 45 N R 8 W M D
88 Keenan mine NE ¼ sec 7 T 43 N R 9 W M D
89 King Solomon mine sec 14 T 38 N, R 12 W M D
90 Klamath River dredge sec 16 T 46 N R 7 W M D
91 Last Chance mine SE ¼ sec 23 T 48 N R 8 W M D
92 Lincoln Gold Dredging Co sec 29 T 45 N R 7 W M D
93 Long Gulch mine sec 8 T 45 N R 7 W M D
94 Lucky Boy mine sec 33 T 17 N R 8 E H
95 Lumgrey mine sec 22 T 47 N R 8 W M D
96 Mammon group sec 14 T 41 N R 7 W M D
97 Marath Mining Corp SE ¼ sec 7 T 46 N R 6 W M D
98 Mattoon mine sec 34 T 45 N R 9 W M D
99 Mayland Mining Co secs 18 19 T 39 N R 11 W M D
100 Middle Fork mines sec 11 T 45 N R 8 W M D
101 Midland Company Inc sec 24 T 40 N R 12 W M D
102 Moccasin mine secs 14 15 T 46 N R 10 W M D
103 Mount Vernon Mines Inc sec 26 T 45 N R 8 W M D
104 Narcol Mining Co sec 16 T 39 N R 11 W M D
105 Olera Mines, Inc sec 17 T 40 N R 8 W M D
106 Oom Paul mine sec 12 T 43 N R 10 W M D
107 Oro Grande Mining Co (McKeen mine) sec 36 T 40 N R 9 W M D
108 Quartz Hill mine sec 16 T 45 N R 10 W M D
109 Rainbow mine (Victory Gold Mines) secs 16 17 20 T 40 N R 10 W, M D
110 Roxbury placer secs 6 7 8 T 45 N R 10 W M D
111 Smith Spellenberg mines sec 13 (?) T 10 N R 7 E H
112 Salmon River Gold Dredging Co sec 30 T 40 N R 11 W M D
113 Salmon River Mines Co sec 12 T 39 N R 10 W M D
114 Schroeder mine sec 17 T 43 N R 8 W, M D
115 Scandia No 1 sec 7 T 46 N R 10 W M D
116 Scandia No 2 Moccasin sec 15 T 16 N R 7 E H
117 Scott Bar Mines Inc secs 16 21 T 45 N R 10 W M D
118 Security mine sec 15 T 39 N R 11 W M D
119 Siskiyou County mine sec 31 T 18 N R 7 E H
120 Smith and Myers mine sec 26 T 40 N R 11 W, M D
121 Sourdout placer sec 24 T 48 N R 8 W, M D
122 Stenshow secs 28, 29 32 T 13 N R 6 E, H
123 Sunnyslope (Mu..en) mine sec 2 T 40 N R 9 W M D
124 Swede Hickey placer sec 27 T 40 N R 12 W M D
125 Taylor Creek mine sec 12 T 39 N R 10 W M D
126 Test Mining Company sec 33 T 40 N R 12 W M D
127 War Horse group sec 9 T 45 N R 8 W M D
128 Webber dredge sec 29 T 46 N R 7 W M D
129 West Branch Dredging Co sec 35 T 45 N R 9 W M D
130 White Bear mine (Mayland Mining Co) secs 18 19 T 39 N R 11 W M D
131 White placer mine sec 12 T 45 N R 8 W M D
132 Yreka Gold Dredging Co sec 13 T 46 N R 12 W M D
133 Yuba Consolidated Gold Fields Siskiyou Unit secs 6 7 T 40 N R 8 W M D
134 Zarina mine group sec 27 T 41 N R 10 W M D

GRAPHITE

135 Black Jack Crystal Eaktaker sec 12 T 47 N R 12 W M D

LIMESTONE

136 Electro Lime and Chemical Corp secs 4 5 8 T 42 N R 6 W M D
137 Mt Shasta Limestone sec 12 T 42 N R 7 W M D

LEAD

138 Belfrey mine secs 28 29, T 41 N, R 7 W M D

MANGANESE

139 Colgrove manganese (Fort Jones) sec 2 T 43 N R 9 W M D
140 Fort Jones manganese sec 2 T 43 N R 9 W M D
141 Gray Ledge mine sec 21 T 40 N R 10 W M D
142 Joe Allen mine sec 8 T 44 N R 8 W M D
143 Mayland Mining Co White Bear mine secs 18 19 T 39 N R 11 W M D

MINERAL WATER

144 Shasta Water Co sec 7, T 39 N R 3 W M D
145 Stewart Mineral Springs sec 11 T 41 N R 6 W M D
146 Table Rock Spring sec 20 T 45 N R 4 W M D

PLATINUM

147 Yuba Consolidated Gold Fields secs 6 7 T 40 N R 8 W M D

PUMICE

148 Foss claims secs 22 27 34 T 44 N R 4 E M D
149 Glass Mountain Industries secs 34 35 T 44 N R 4 E M D
150 Glass Mountain Vocalite Co secs 1 2 T 43 N R 4 E secs 25, 26 34 35 36 T 44 N, R 4 E M D
151 John Madsen secs 25 26 35 T 44 N R 4 E M D
152 Mt Hoffman pumice claim sec 28 E ½ sec 29 T 44 N R 4 E M D
153 Shasta group sec 22 T 42 N R 4 W M D
154 Volcanic Products Corp T 44 N, R 4 E M D

QUICKSILVER

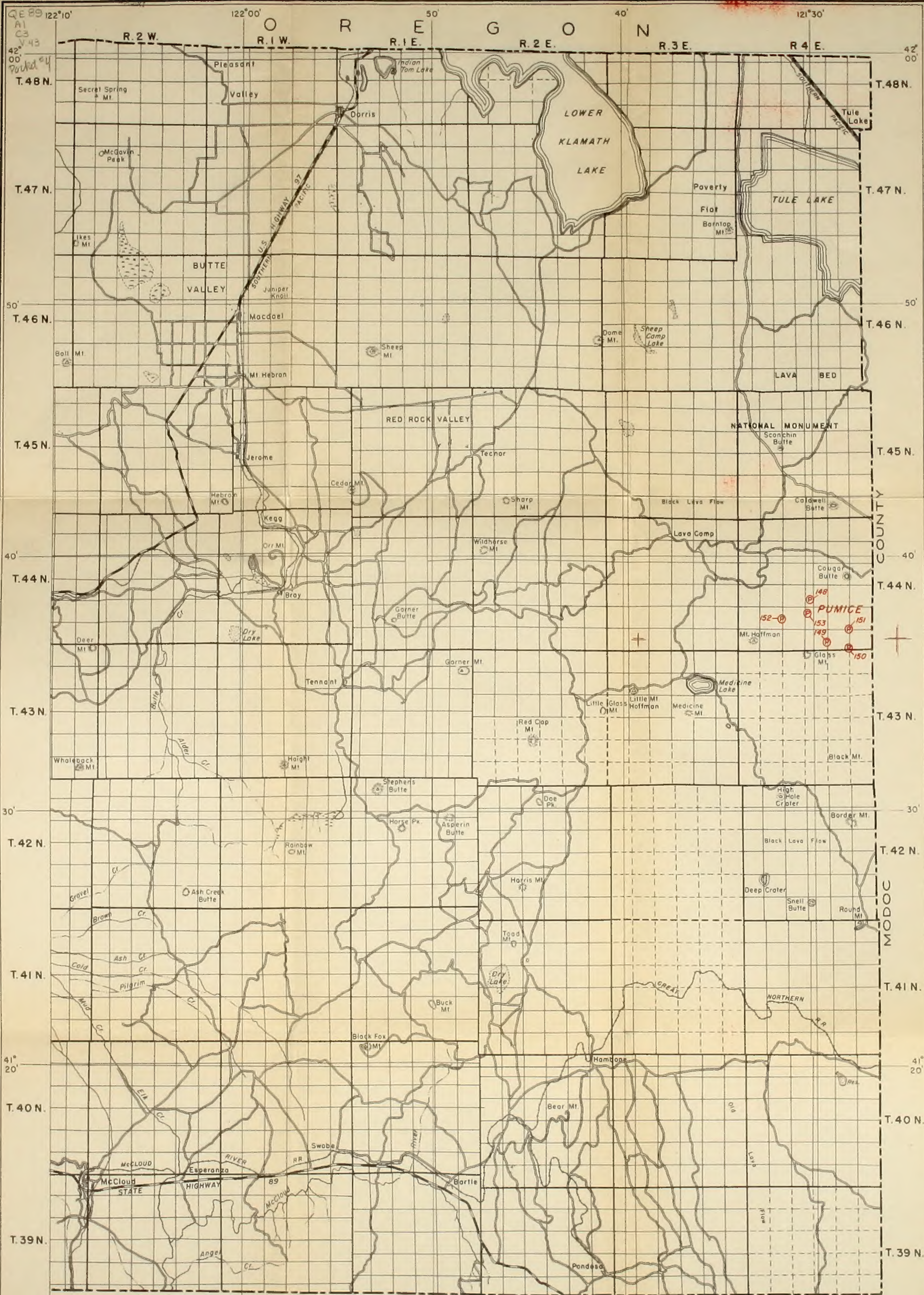
155 Great Northern quicksilver secs 13 14 24 T 47 N R 8 W M D
156 Horse Creek mercury secs 15 16 T 46 N R 10 W, M D

SANDSTONE

157 Anthne (Weeks) quarry sec 13 (?) T 45 N R 7 W M D
158 Fiok Bros quarry sec 13 T 45 N R 7 W M D
159 Southern Pacific Co sec 29, T 47 N R 6 W M D

MISCELLANEOUS STONE

160 Cement & Co sec 10 T 42 N R 6 W M D
161 Mt Shasta (Kollinger) sec 5 T 40 N R 4 W M D
162 A Young sec 4 T 44 N R 7 W, sec 2 T 42 N R 6 W M D



MAP OF EASTERN PORTION OF SISKIYOU COUNTY, CALIFORNIA

SHOWING LOCATIONS OF MINERAL DEPOSITS

BASE FROM U.S. FOREST SERVICE MAP SHASTA NATIONAL FOREST

SCALE 0 1 2 3 4 5 Miles

1947

SEE PLATE 42 FOR WESTERN PORTION OF COUNTY